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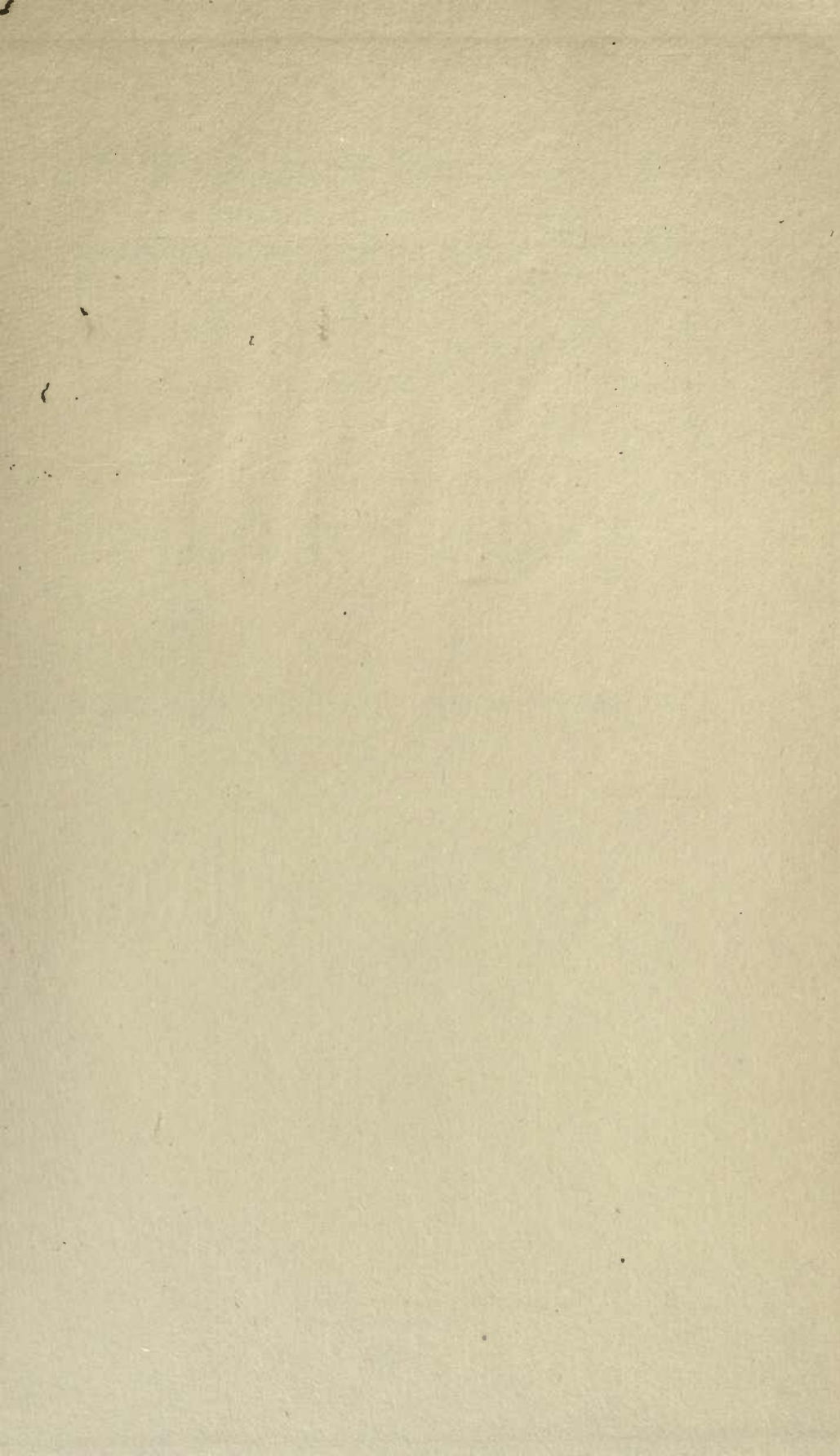
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MISSOURI BUREAU OF GEOLOGY AND MINES

E. R. BUCKLEY, Ph. D., Director and State Geologist.

Vol. V, 2nd Series.

PUBLIC ROADS,

THEIR IMPROVEMENT AND MAINTENANCE.

BY

E. R. BUCKLEY.



THE HUGH STEPHENS PRINTING COMPANY.
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LETTER OF TRANSMITTAL.

BUREAU OF GEOLOGY AND MINES,
ROLLA, MO., February 15, 1907.

To the President, Governor Joseph W. Folk, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen—I have the honor and pleasure to transmit to you a brief report on "Public Roads, Their Improvement and Maintenance," which report has been prepared in accordance with your instructions.

In collecting the information contained in this report, I have had the assistance of the United States Postoffice Department, city engineers and city clerks. The report is not complete, in so much as it does not contain a detailed discussion of the condition of the highways and materials available for their improvement in each of the counties in the State.

The discussion of methods of constructing the various pavements now in use embodies the latest ideas on this subject, and should serve as a guide to all cities and towns that are engaged in constructing permanent pavements.

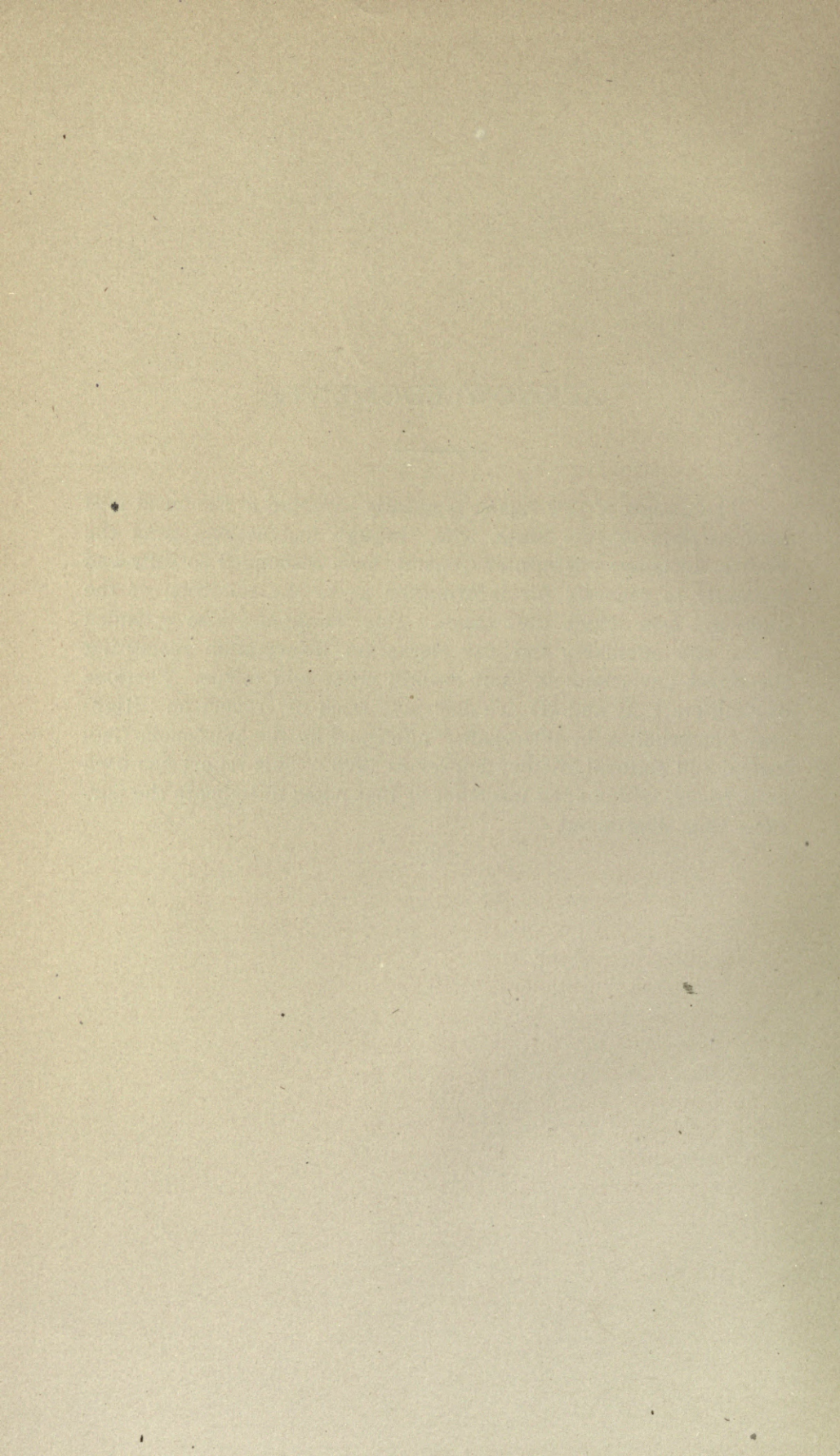
With a full realization of the deficiencies in this report, it is submitted with the hope that it will supply a widespread demand among our people for information on the methods of highway improvement.

I remain, very respectfully, your obedient sir,

E. R. BUCKLEY.

ACKNOWLEDGMENTS.

The author of this report is greatly indebted to the rural free mail carriers of this State, who, through instructions from the Fourth Assistant Postmaster-General, have responded so fully and promptly to requests for information as to the condition of the highways over which they travel. Our thanks are also extended to the city engineers and city clerks for information respecting the street pavements in their several cities and towns. Portions of chapters I, II and III are abstracts from my report on "Highway Construction in Wisconsin," published by the Wisconsin Geological and Natural History Survey in 1903. This report has been used freely, without the insertion of foot notes to indicate the portions thus abstracted.



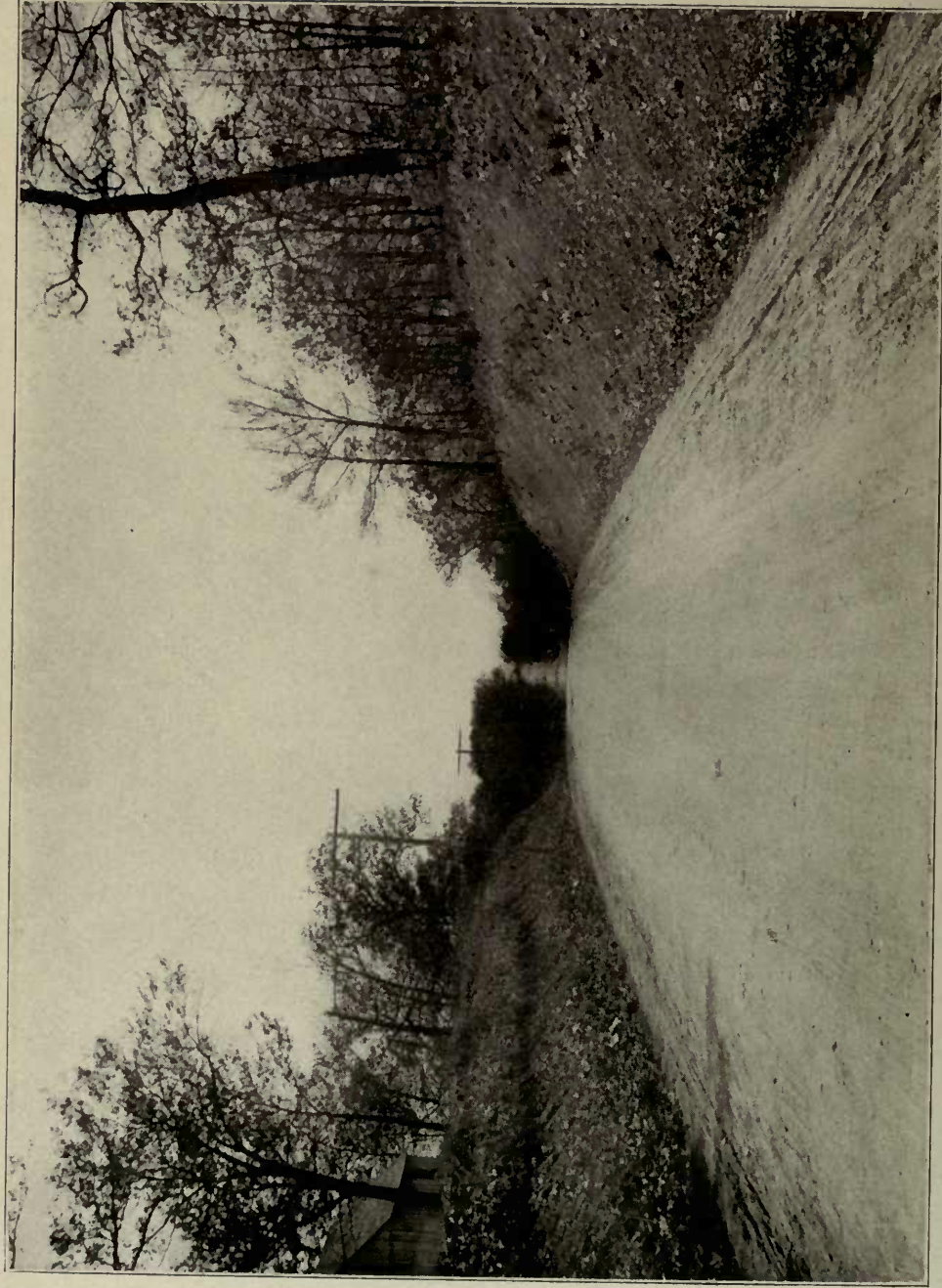
INTRODUCTION.

Up to the present time highways in Missouri have meant narrow strips of land, set apart for the use of the public, connecting different parts of the country. In many parts of the State no attempt has been made to improve the highways further than to make them passable for teams and wagons. At present this condition is undergoing a rapid change and everywhere there is an urgent demand for information as to how to best improve the roads.

The problem of improving the country roads differs in some respects from that of building city pavements. However, the city, town and village should be the places to which the people in the country might turn for practical demonstrations in the science of road building. Strange as it may seem, the streets in many of our towns and villages are in a worse state of repair than the country highways.

The first chapter of this report discusses the agencies through which pavements are destroyed. Chapter II deals with the materials used in improving the highways. The strength, durability and general utility of all materials are fully discussed. Chapter III is a discussion of the methods of constructing the various pavements. The specifications for building various kinds of pavements and sidewalks should be valuable to those who are not familiar with these constructions. Chapter IV on "Drainage," chapter V on "Country Highways," chapter VI on "Materials for Highway Improvements," and chapter VII on "The Present Condition of Rural Highways and City Streets," are especially fitted for those who are beginning the study of the problems connected with highway improvements.





JOPLIN-DUENWEG ROAD, JASPER COUNTY, MO. IMPROVED WITH CHAT IN 1897.



CHAPTER I.

A CLASSIFICATION OF HIGHWAYS AND A DISCUSSION OF THE AGENTS THROUGH WHICH THEY ARE DESTROYED.

Any strip of land set apart for travel, with the exception of railway lines, is referred to as a highway or a roadway. A highway is usually separated from the land on either side by fences or hedges. When fully improved, it should consist of three quite distinct parts, known as the road or street, the sidewalk or footpath, and the park or terrace area. The road or street, which usually occupies the middle of the highway, should be separated from the terrace areas by a curb. Between the terrace area and the property line on either side should be located the sidewalk or footpath. Sometimes these are built up to the property line and at other times to within 12 or 18 inches. In cities and towns, the sidewalk is usually improved before the street, while in the rural districts one seldom finds a sidewalk, even though the street may be paved. The order in which these parts of the highway are improved depends upon the needs of the public.

Most of the highways in this State are owned and maintained by the public, although remnants of the toll gate or private road system still remain in some sections. The public highway is constructed and maintained by the public through the usual avenue of taxation. Private highways, consisting of toll roads and private roads, are built and maintained at private expense. Both of these are unimportant in Missouri, and will be given very little consideration in the following discussion. Within a few years there will be no toll roads in Missouri. Private roads usually extend short distances, connecting private property with the public highways.

Depending upon the location of public highways, they are known as state, county and town roads and city and village streets. For convenience, the Massachusetts highway commission has classified highways into heavy traffic, light traffic and residential. A majority of our highways, including those in the rural districts, come under the head of light traffic. Those in the warehouse districts of our large cities are heavy traffic, while those in the residence districts are residential.

The statutes of Missouri specify that "All public roads shall be not less than 30 or more than 60 feet wide, to be determined by the county court according to the utility and necessity of such road." This provision does not apply to city streets, the width of which is determined by ordinance regulating the same.

The highways, both in the country districts and in the cities, towns and villages in Missouri, are sufficiently wide to admit of a considerable variation in the width of the pavement. The width of the park areas and the sidewalks vary greatly, depending upon the location of the highway and amount and character of the traffic. The width of the pavement, park areas and sidewalks should be in proportion to the requirements of traffic. Except in the business sections of our cities, a pavement 20 feet wide, sidewalks 5 feet wide and park areas of 15 feet are usually sufficient to meet the demands of traffic as well as to satisfy the aesthetic taste of the public. The tendency at the present time is to build street pavements unnecessarily wide and the sidewalks uncomfortably narrow. The former results in an unnecessary expense, both for construction and maintenance; the latter serves as a constant annoyance to the individuals using the sidewalks.

The highway should be paved from gutter to gutter, and the pavement should be no greater than is necessary to accommodate the traffic to which it will be subjected after the improvements have been made. A narrowing of the highway is not advocated, reference being made simply to the pavement. It is thought that streets should be broad and wide, giving light and air, and avoiding danger of accident incident to narrow roadways. If business, in years to come, should absorb what is now a residence district, it will be an easy matter to attach a portion of the park area to the pavement. Park areas between the pavement and the sidewalk increase very greatly the valuation of the adjacent property by removing from the front yard the noise and dirt resulting from traffic.

The perfectly improved highway consists of the pavement, the gutter, the curb, the park area and the sidewalk. These together may be considered the constructional parts of a highway. They must be built out of materials which will wear well, and it is often necessary to ship them from distant places. Frequently the cost of transportation and construction are so great as to demand of the authorities a most careful supervision, so that nothing but the best and most durable substances are used.

AGENTS OF DESTRUCTION.

Before taking up a discussion of the materials used in the improvement of highways and their efficacy to withstand the agents of destruction, let us consider the destructive agents and the manner in which they operate. It is extremely important that everyone engaged in the improvement of the highways should be familiar with those agencies operating to destroy the improvements made yearly upon our public thoroughfares. Without this understanding, one cannot intelligently select the best materials for building pavements and sidewalks.

The agents through which the destruction of a pavement is brought about may be classified as follows:

- I. Temperature Changes.
 - (a) Unequal expansion and contraction of the pavement and its constituents.
 - (b) Stresses caused by the freezing of water in pores, cavities or crevices in the pavement.
- II. Mechanical Abrasion.
 - (a) Water.
 - (1) Impact.
 - (2) Running off from surface.
 - (b) Impact and abrasion of horses' hoofs.
 - (c) Impact and abrasion of feet of pedestrians.
 - (d) Impact and abrasion of wheels of wagons.
 - (e) Weight of traffic and abrasion of sleigh runners.
 - (f) Internal friction.
 - (g) Wind.
- III. Growing Organisms.
 - (a) Weeds and grasses.
 - (b) Trees.
- IV. Chemical Decomposition.
 - (a) Solution by water.
 - (b) Evaporation by the atmosphere.
 - (c) Decomposition by acids.

Temperature Changes.—It is well known that any substance, such as stone, brick, concrete or asphalt, suffers a material amount of contraction and expansion as a result of variations in the normal atmospheric temperature. The rate of expansion and contraction of all substances used for paving is an appreciable amount and should receive consideration. Mr. W. H. Bartlett has determined, experimentally, the actual expansion of different kinds of stone brought about by an increase in temperature. He obtained the following results:*

Granite,	.000004825 inch per foot for each degree Fahr.
Marble,	.000005668 inch per foot for each degree Fahr.
Sandstone,	.000009532 inch per foot for each degree Fahr.

*Am. Journal of Science. Vol. 22, 1832, P. 136.

The annual variation in temperature for this latitude frequently amounts to 100° Fahr., while the diurnal change is often 30° to 40° Fahr. A change of 100° Fahr. would increase the diameter of a 100-foot sheet of granite about two-thirds of an inch. This is an appreciable amount, and if the sheet of granite did not occur in blocks, the expansion or contraction would result in rupture. In case blocks of granite are closely fitted together and confined on all sides, an increase in temperature of 100° would either displace or break some of their number. On the other hand, if the temperature should be lowered at 100° , the stresses would be sufficient to draw the blocks apart, leaving *interspaces* in the form of cracks. These conditions are such as to make it imperative that in constructing pavements allowance be made so that expansion and contraction may take place without resulting in rupturing or displacing parts of the pavement.

I have been unable to find determinations of the co-efficient of expansion of paving brick, asphalt and wood. However, it is known that pavements constructed out of these materials will be injured unless expansion joints are provided. During the hot summer months asphalt becomes viscous and will roll up in waves before the wheels of a vehicle. Many times during extremely cold weather cracks have been known to form in this kind of a pavement.

I know of no pavement which is absolutely impervious. Water will find its way into the pores or interstices and along the cracks and crevices of any pavement. Should the pores and cracks be filled with water at the time of freezing, there is danger of permanent injury to the pavement. If the interstices are very small, it will require a long period for the water to drain off. Rocks which are only slightly pervious absorb water very slowly and retain the same with great tenacity.

Water, in passing from the liquid to the solid state, exerts a force equal to about 150 tons to the square foot. This stress is sufficient to result in the widening of cracks and crevices and eventually in the disintegration of the pavement.

The danger attendant upon the freezing of the water which fills the pores of a rock must not be confused with the freezing of water which collects along the parting planes. The latter is a more conspicuous cause of decay of stone, brick and concrete than the former. It is especially active at the position known as the water line.

Granting that cracks and pores occur in the pavement, pro-

vision should be made for the rapid removal of the water before it has had an opportunity to penetrate below the surface.

From the foregoing it is evident that the surface of a pavement should be constructed out of materials which are free from fissile planes and contain a small percentage of pore spaces. The danger from the freezing of included water necessitates the filling of the joints of a block pavement with a cement mortar which will adhere to the sides of the blocks. As a general proposition, the surface of a pavement should be made, as far as possible, impervious to water.

MECHANICAL ABRASION.

Water is one of the most active agents in the destruction of pavements. The effects produced upon the land surface by the rain are in a less degree apparent upon pavements. The forces are equally as great, but the greater resistance of pavements makes their effect far less apparent. A pavement may be said to be durable in proportion to the effects produced by the rainfall. This must not be construed to mean that the effect of the rainfall is the only criterion by which to judge the suitability of a pavement.

The *impact of rain drops* falling on a pavement exert a force tending to overcome the adhesion which binds the particles together.

Particles which have been loosened are picked up by the water which flows off of the surface, and these, in conjunction with the water itself, act as a file to break off other particles, which in turn are picked up and carried away.

A pavement which is imperfectly constructed, has unequal declivities on opposite sides of the crown, has a rough surface as a result of small ridges and gulleys, and varies in hardness and texture, will not wear uniformly. *Ideal pavements have smooth surfaces; they have the same declivities on both sides of the crown; and the material of which the surface is composed is uniform in hardness, texture and composition.* The nearer the pavement approaches these conditions, the less will be the danger of injury from water flowing over the surface. A greater part of the wear occasioned by flowing water is accomplished by the solid particles held in suspension or rolled along the surface of the pavement. Therefore, *the less debris that the water can pick up in flowing off from the surface, and the shorter the distance that the water has to travel in passing from the surface of the pavement to the gutter, the less will be the wear.* These principles should be borne in mind by

those who are interested in maintaining dirt roads. They may decrease the number and size of the channels formed in the road during heavy rain storms.

The formation of streams is accounted for mainly by inequalities in the hardness of the rocks and unequal declivities of the surface. If we would reduce to a minimum the effect of the rain storm, we should construct pavements out of homogeneous materials which are hard and compact, and the pavements should be so constructed as to convey the water off from the surface by the shortest course and without collecting it into rills or rivulets.

The *impact of horses' hoofs*, as they strike the pavement, besides resulting in a simple impact, may produce abrasion. The impact may result in breaking or cracking portions of the pavement, while the sliding or rubbing of the shoe acts as a rasp, separating small particles from the pavement. The abrasion resulting from this agency is very great. The manner in which the pavement is worn by the impact of the horses' hoofs depends upon the kind of pavement. A macadam or other sheet pavement, such as asphalt, usually wears gradually,—softer portions most rapidly. A block pavement, unless the joints are completely filled with cement, presents numerous corners and edges which may be split off by any sharp blow, such as the impact of a horse's hoof. Brick, stone block, asphalt block and cement block pavements suffer in this manner. Simple abrasion of a pavement increases with conditions favorable for slipping or sliding. As the blocks of a block pavement become rounded at the surface, the result of abrasion from slipping increases within the limits of the block. Granite blocks often become rounded and polished on the surface as a result of this slipping action.

Wagon wheels wear a pavement both through impact and abrasion. The abrasion results from a sliding or slipping action as in the case of horses' hoofs. Injury through impact results chiefly from unevenness in the surface of the pavement. The corners and edges of brick and stone blocks are often broken by the impact of the wheels. Perfectly smooth pavements suffer very little from the impact of wheels although abrasion through the sliding of wagons is worthy of consideration. Sleigh runners occasionally cut through the snow onto a pavement, acting as a rasp and wearing more or less that portion of the pavement with which they come into contact.

Very heavily loaded transfer and other wagons place a pavement under stresses which frequently crush either the surface or

foundation. From this cause a pavement or its foundation may be broken into blocks similar to those formed when a sheet of iron is similarly treated. In cases where the surface of a pavement is soft, the wheels form ruts, which hasten very rapidly the deterioration of the pavement. In any event, the impact and abrasion resulting from the hoofs of horses and the wheels of vehicles are intensified as the weight of a load increases.

Internal friction is an important agent of mechanical wear only where the fragments composing the pavement are loosely cemented and free to move. The wear resulting from internal friction is evident chiefly in the broken stone pavements where the interstices between the fragments are left void. Any movement of these fragments under the pressure of moving vehicles has a tendency to round off their corners, on account of which their bonding capacity is lessened. Gilispie says, "If a thick coat of crushed rock be laid on at once, there is very great destruction of the material before it becomes consolidated, if it ever does so. The stones will not allow one another to be quiet, but are continually elbowing each other and driving their neighbors to the right and to the left. This constant motion wears off the angular points and reduces the stone to a spherical shape, which, in conjunction with the amount of mud and powder produced, destroys the possibility of any firm aggregation, and the road never retains its proper condition of hardness." It is important that an immovable pavement be constructed, one in which there is a minimum of internal friction between the component parts.

Wind, as well as water, is an active agent of erosion. Driving sand or dust slowly abrades the surfaces of pavements. This agent is not very active in a humid climate like Missouri, but it assists in the eventual complete disintegration of the pavement.

GROWING ORGANISMS.

Vegetation exerts both a protective and destructive influence on a pavement. Some pavements, such as asphalt, do not sustain the growth of vegetation. Macadam, wooden block, stone block, brick and similar pavements often afford a foothold for vegetation, which, if given an opportunity, will often cover the street with tufts of grass and weeds.

Grass growing on the surface of a pavement will protect it from abrasion of running water, collecting and retaining the detritus which would otherwise be removed to the gutters. The roots penetrating between the blocks promote disintegration, while

the retention of the moisture, combined with the acids resulting from the decay of the vegetation, hasten the destruction of the pavement through their chemical action. Besides this, grass and weeds filling the gutters and covering the streets are unsightly evidences of neglect.

With reference to shade trees, Mr. Law, in a volume on "The Art of Constructing Common Roads," says: "Few persons are aware of the extent to which a road may be injured by high hedges or lines of trees. Trees are worse than hedges, because they not only deprive the road of the action of sun and air, but they further injure it by dripping rain from their leaves, as a consequence of which the road is kept in a wet state long after it would otherwise have become dry." He further adds, " * * * from an engineering point of view, everything that interferes with the sun and prevents the circulation of air is objectionable." We cannot meet all the requirements laid down by the engineer. Hedge fences may be necessary in some sections of the country, but they have proven so expensive in every way that they are being rapidly replaced by wire. There is a universal demand for shade trees, and the prevention of their destructive influence must be brought about by a proper construction of the pavement.

Pavements and sidewalks are often bulged and broken through the growth of the roots of nearby trees. Where city streets are wide enough to permit the construction of terrace areas, little or no difficulty is experienced from the growth of shade trees. Injury from this cause may also be prevented by covering roots with sewer pipe, broken lengthwise. The pipe should be large enough to allow growth for a number of years without crowding the walk.

CHEMICAL DECOMPOSITION.

Rain water, carrying an excess of carbon dioxide and humus acids, may be injurious to pavements in case it penetrates below the surface. Chemical changes are most liable to effect asphalt, limestone and bituminous pavements. Asphalt and bituminous pavements, especially, will disintegrate if water is allowed to stand upon them.

Asphalt and coal tar pavements are also liable to be effected by the atmosphere alone, through which oxidation may take place. The amount is an appreciable quantity during the lifetime of these pavements.

CHAPTER II.

MATERIALS USED IN IMPROVING HIGHWAYS.

The permanence of a pavement depends upon the kind of materials used, the manner of construction, the character of the sub-soil and the drainage. The most important of these is that of materials. All other conditions may be perfect, but if the materials are poor, the pavement will be unsatisfactory.

In the improvement or repair of the highways, all sorts of materials, both vegetable and mineral, are used. Ruts and gulleys are filled with material which is nearest at hand, such as brush, corn stalks, gravel, shavings, stone, straw or even clay. Low places in the roads, where water accumulates, are likewise filled with a variety of materials in order to force the water to settle on some other portion of the land.

In the rural districts, where pavements cannot be constructed on account of their cost, the road improvements become chiefly a question of drainage, which involves the shaping of the road-bed out of the materials immediately at hand. In this chapter, it is not intended to discuss this phase of improving highways. Our attention will be directed to a consideration of the materials which may be used in the construction of so-called permanent pavements.

Materials for street improvements may be classified as (1) natural, and, (2) manufactured. Among the natural materials may be mentioned, clay, gravel, sand, shells and wooden blocks, stone—including asphaltic limestone and sandstone, granite, limestone, sandstone, shale, slate, quartzite and trap rock. The most important manufactured products are asphalt, asphalt blocks, brick, cement, cement blocks, cement pipe, cinders, coal tar, drain tile, charcoal, glass, gumbo, iron pipe, petroleum, clay and vitrified sewer pipe. Each one of these is or has been used in the construction of some part of the various kinds of pavements. In the following pages these materials will be considered, with special reference to their adaptibility for use in the construction of different kinds of pavements.

ASPHALT.

Asphalt, or asphaltum, is a term applied to a number of different substances which are known more specifically as grahamite,

gilsonite, uintaite and albertite. It has a black or brownish color, and is brittle when struck a sharp blow with a hammer. It melts at a temperature of 200° F.

Asphalt occurs in beds, in veins and impregnating porous limestone and sandstone. The most extensive known deposit of asphalt is on the island of Trinidad, near the coast of Venezuela. On this island it occupies a basin having an area of about 160 acres. In the United States, asphalt is, or has been, obtained from deposits in California, Texas, Pennsylvania, Kentucky, Indian Territory, Arkansas, Missouri and Utah.

In California, asphalt is obtained through the distillation of petroleum. This is known as oil asphalt. The consumption of this kind of asphalt is increasing yearly.

Asphalt from different localities varies greatly in composition. Before being used, it is usually refined, by which process the water, earth and vegetable matter are removed.

The following tables indicate the chemical composition of both crude and refined products:

ANALYSES OF CRUDE TRINIDAD ASPHALT.*

	Per cent.	Per cent.	Per cent.
Water.....	16.37	27.85	27.85
Asphalt.....	39.83	38.14	38.14
Earthy matter.....	33.99	26.38	.....
Vegetable matter.....	9.31	7.63	34.01
Totals.....	99.50	100.00	100.00

ANALYSES OF REFINED ASPHALT.*

Place.	Trinidad.	Mexico.	Peru.	Cuba.	Colombia.	Palestine.
Chemist.....	Bowen.	Regault.	Bossin-gault.	Bossin-gault.	.....	Kayser.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon.....	85.89	80.34	88.67	81.50	88.31	80.00
Oxygen.....	.56	10.09	1.65	6.60	1.68	.40
Hydrogen.....	11.06	9.57	9.68	9.60	9.64	9.00
Nitrogen.....					.37	10.00
Sulphur.....	2.49					.60
Ash.....						
Totals.....	100.00	100.00	100.00	100.00	100.00	100.00

*Mineral Industry, Vol. II, p. 45.

In selecting asphalt for street paving, one should know the composition and permanent cementing qualities of the different brands that are under consideration; their solubility in carbon disulphide, alcohol, turpentine, ether, petroleum and naphtha; and

their softening point or the temperature at which the asphalt flows.

It is supposed that at a temperature of less than 70° F. asphalt will remain unchanged. At a temperature of 70° F., or above, asphalt slowly volatilizes. During the summer months in the temperate zone, this temperature is often reached, and disintegration through volatilization takes place.

BRICK.

Common building brick and vitrified paving brick are used extensively in street improvements. Building brick are used chiefly in the construction of sewers, in the foundations for vitrified pavements and in other positions removed from the abrading action of the street traffic.

Building brick, which are used in street constructions, should be hard and well burned. The semi-vitrified brick from the arches of up-draft and from the top of down-draft kilns are most suitable. Non-porous hard brick, except paving brick, manufactured by any process, are known as sewer brick. Common hard burned building brick are sometimes used for sidewalks and cross walks. As a rule, they are too soft and wear unevenly. A vitrified paving brick is the only brick suitable for either sidewalks or street pavements.

The shale or clay used in the manufacture of vitrified brick is similar to that used in the manufacture of vitrified sewer pipe. The following analyses illustrate the composition of clays and shales from which four well-known varieties of paving brick are manufactured.

COMPOSITION OF CLAYS USED IN MANUFACTURING PAVING BRICK.

	I ¹ .	II ² .	III ³ .	IV ⁴ .
SiO ₂	68.96	61.76	60.34	57.90
Al ₂ O ₃	17.95	18.82	24.26	21.29
H ₂ O combined.....		2.94	1.56	6.00
H ₂ O moisture.....				1.30
Fe ₂ O ₃	7.25	2.04	7.73	7.21
CaO.....	0.76		1.85	0.29
MgO.....	1.47	1.45	0.70	1.53
K ₂ O.....	2.38	3.49	3.12	3.44
Na ₂ O.....				0.61
Miscellaneous.....	1.05			
Grand totals.....	100.00	100.00	99.16	99.97
Age.....	Coal meas.	Coal meas.	Coal meas.	Coal meas.

¹ No. I—From Galesburg, Illinois, Clay Worker, April, 1895 (Meade), Indianapolis.

² No. II—From Streator, Illinois, Clay Worker, April 1895. (Meade), Indianapolis.

³ No. III—From Des Moines, Iowa, Clay Worker, April, 1896, (Meade), Indianapolis.

⁴ No. IV—From Canton, Ohio, Clay Worker, May, 1894, (Orton), Indianapolis.

The quality of a paving brick made out of a suitable clay depends upon the method of preparing the clay and the manner of drying and burning the brick. Absolute uniformity in the degree of vitrification of the brick in all parts of a kiln has never yet been obtained.

Owing to the differences in the degree of vitrification in different parts of a kiln, the brick are usually sorted into three different grades, called Nos. 1, 2 and 3. Whether or not the brick are thus graded, as well as the care with which the grading is done, depend upon the condition of the market. If the demand exceeds the supply, less care is exercised in grading than when the reverse condition exists. No. 1 brick are made to include those that are neither under nor over-burned, having a perfect shape and thoroughly vitrified; No. 2 paving brick include those that have not been completely vitrified, but are otherwise perfect in shape; No. 3 paving brick include those that are in any way broken, fractured or distorted. The over-burned brick, which cannot be included in this grade, are known to the trade as "clinkers." The standard upon which is based the grading of brick at different factories varies greatly. For this reason the No. 1 brick from different localities are not equally strong and durable. As a result of careless grading and a lack of uniformity in burning different kilns of brick, the standard of grading may vary from time to time at the same factory. For these reasons it is important that each consignment of brick for street paving should be thoroughly tested before being accepted.

Tests to determine the strength and durability of paving brick should include: (1) specific gravity, (2) porosity, (3) crushing strength, (4) transverse strength, (5) hardness, and (6) capacity to resist abrasion. Some of these tests are never made before accepting a consignment of paving brick. Judgment as to their quality is frequently determined from the results of the absorption and abrasion tests alone.

Hardness may be determined by using Moh's scale of hardness. The loss in the weight of the brick is a measure of the abrasion. A well vitrified brick has a hardness of between 6.5 and 7.

Absorption can be obtained by saturating the brick in water and weighing before and after on chemical balances.

A well vitrified brick should not absorb more than 2 per cent. of water. However, brick which absorb more than 2 per cent. are sometimes more durable than those that absorb less. The size of the pore spaces is a factor which is not always given sufficient con-

sideration. This, however, is more important than the total percentage of pore space.

The loss, due to abrasion, can be determined by the use of a machine known as the "Rattler." This machine is usually a polygonal cylinder, from 24 to 30 inches in diameter, with a length of 36 to 42 inches. From five to ten brick are placed inside and the machine is revolved at a rate of 25 revolutions a minute for about an hour. In most cases a quantity of scrap iron is placed in the rattler with the brick.

Most engineers specify that a brick used in street paving shall not lose more than 10 per cent when subjected to a test of one hour in a standard rattler.

Several kinds of rattlers are in use in the United States. Each is so constructed that the results obtained from one cannot be compared with those obtained from another.

The specific gravity may be determined by the usual method of weighing the brick in air and then in water, saturated with water. The loss of weight in water divided by the dry weight will give the specific gravity. The specific gravity of vitrified brick ranges from 2.2 to 2.4.

The crushing strength of a well vitrified brick is frequently as high as 20,000 pounds per square inch, although a brick which will sustain a pressure of 6,000 pounds per square inch is strong enough for most pavements.

The cross-breaking strength is expressed by the modulus of rupture, which ranges from 1,000 to 3,000 pounds per square inch. It seldom happens that a vitrified brick has less than the required cross-breaking strength.

A uniform method of determining the wearing quality of a paving brick should be adopted in order that comparative tests may be obtained.

CEMENT.

Cement is composed of a mixture of aluminum silicates of calcium or iron. These silicates are usually produced by burning either an argillaceous limestone or a mixture of limestone and shale. The necessary ingredients for the manufacture of cement are calcium carbonate, alumina and silica. Some rocks contain these constituents in approximately the correct proportions for the manufacture of cement. Such a stone is commonly known as hydraulic limestone, and from it natural cement may be manufactured. Scientific investigations have shown, however, that the best cement,

known as Portland cement, is obtained by mixing and burning definite proportions of alumina, silica and calcium carbonate. These are obtained by mixing clay or shale with marl or limestone.

The following tables give the composition of a few typical limestones, marls and clays, used in the manufacture of Portland cement:

ANALYSES OF LIMESTONE AND MARLS.*

Locality.	Chalk, England (Reed),.....	Cement rock, LaSalle, Ill.,...	Cement rock, Siegried, Pa.	Marl, Sandusky, Ohio.....	Marl, Syracuse, Indiana.....
Calcium carbonate.....	98.57	88.16	69.91	91.77	88.49
Magnesium carbonate.....	0.38	1.78	4.28	0.53	2.71
Calcium sulphate.....				3.19	1.58
Silica.....	0.64	9.20	17.32	0.22	1.78
Alumina.....	0.16	1.00	7.07	1.22	0.91
Iron oxide.....	0.08	0.30	2.04	0.40	0.39

*"The Cement Industry," The Engineering Record, 1900, pp. 12-13.

ANALYSES OF TYPICAL CLAYS.*

Locality.	Medway, England.	Harper, Ohio.	Sandusky, Ohio.	LaSalle, Illinois.
Silica.....	70.56	51.50	65.41	54.30
Alumina.....	14.52	13.23	16.54	19.33
Iron oxide.....	3.06	3.30	6.06	5.57
Lime.....	4.43	11.52	2.22	3.29
Magnesia.....		3.45	1.88	2.57
Carbonic acid.....	3.47	12.85		
Alkalies.....	3.95			

In the construction of pavements we are concerned more with the quality of the cement than with the methods of manufacturing the same. In determining the quality, the following tests are made, namely: specific gravity, fineness, setting property, tensile strength and soundness. Of these the tensile strength test is the most important. A full discussion of the subject of testing cement may be had by reference to almost any text-book on this subject. A small volume on the "Examination of Portland Cement," by Richard K. Meade, brings together in concise form much valuable information on this subject. The following is a table showing the

comparative tensile strength of cement mortars, both Natural and Portland:

TENSILE STRENGTH OF CEMENT-MORTAR.**

Composition of the mortar.		Age of mortar.							
		Rosedale (natural).				Portland.			
Cement.	Sand.	1 week.	1 month.	6 mos.	1 year.	1 week.	1 month.	6 mos.	1 year.
1	.....	100	180	275	800	300	400	450	500
1	1	60	100	170	224	175	250	340	375
1	2	25	60	125	170	120	150	245	290
1	3	20	40	80	120	90	110	175	220
.....	4	15	25	60	90	75	75	130	170
.....	5	10	15	50	80	60	65	110	130
1	6	6	10	45	75	50	36	90	100

**The Cement Industry," The Engineering Record, 1900, pp. 12-13.

**Highway Construction, 1900, A. T. Byrne, p. 273.

There are two Portland cement factories in Missouri, both of which manufacture a superior grade of cement. One of these factories, operated by the St. Louis Portland Cement Company, is located at Bellefontaine, on the Missouri river, just north of St. Louis. The other, which is operated by the Atlas Portland Cement Company, is located about two miles south of Hannibal. Two additional plants are in process of construction, one near Kansas City and the other south of St. Joseph.

In highway construction, cement is now used in making concrete foundations to asphalt, brick, stone block, wooden block and asphalt block pavements; in the manufacture of sewer pipe, curbing, gutters, granolithic and granitoid walks, sewers, catch basins, cross-walks and as grouting filling the joints in block pavements.* For most of these purposes, Portland cement is preferable to natural cement. The latter, however, may be used with perfect safety in the construction of concrete foundations, sewers, catch basins, etc.

CEMENT PIPE.

There are a number of factories in this State manufacturing sewer pipe out of cement. For this purpose, cement, gravel and sand are used. The pipe that are thus made are impervious, strong and durable, equal in quality to most vitrified clay pipe.

*There are also numerous other less important uses, such as hitching posts, stepping blocks, retaining walls, etc.

Tunnels, large sewers, culverts and other underground constructions are now being built mainly out of concrete. However, strength, durability and cheapness are the chief considerations, and for this reason cement concrete is superseding brick and similar materials.

CHARCOAL.

In some localities charcoal has been used to make temporary improvements to the highways. In the absence of slag or cinders, it might be used successfully as a foundation for granolithic walks and gutters. It is, perhaps, too expensive to be used in most localities.

CINDERS.

Cinders are used mainly in making foot paths, in temporarily improving highways and for foundations to cement walks and cement curbs and gutters. In the construction of granolithic walks, curbs and gutters, they are one of the very best materials for the foundation. They are also used to advantage in the improvement of highways, especially in surfacing streets which have been covered with a layer of coarsely broken stone.

Large manufactories, railroads and other concerns using coal for fuel accumulate great quantities of cinders, which can usually be obtained without charge, or at least at a very small cost. A small clinker, such as is made by some grades of soft coal, is most desirable.

CLAY.

The term clay, as used in highway construction, is a plastic or sticky mass of earth of indennite composition. Pure clay is composed entirely of the mineral kaolinite. Clay, as it is commonly known, consists, in addition to kaolinite, of quartz, iron oxide, calcite and other minerals in variable quantities.

In the improvement of highways the value of clay is mainly in its so-called cementing property, on account of which it becomes hard when dry. The clay of a clay-sand road binds the sand grains together, making a moderately smooth, hard surface in dry weather. When sand is mixed with clay, it decreases the plasticity or stickiness of the clay, resulting in a harder road during wet weather. The fine dust which accumulates on a clay road is decreased by adding coarse sand.

The chief value of raw clay is as a binder for gravel and

broken stone. A clay which contains considerable iron oxide is most suitable for this purpose. The amount of clay required for bonding gravel depends upon the composition and properties of the clay. Twenty per cent of clay, which is moderately free from impurities, is about the correct proportion to mix with gravel and sand.

Clay occupies a very unimportant place in the construction of permanent pavements. Occasionally it is used as a bonding constituent for macadam pavements, but should never be used except where it is absolutely necessary. The products manufactured out of clay, such as brick, drain tile, sewer pipe and burnt clay ballast, are very important in the permanent improvement of our highways. These are discussed elsewhere in this chapter.

COAL TAR.

Coal tar is obtained as a by-product in the manufacture of charcoal, coke and gas. The nature of the tar varies with the character of the raw materials, and also with the process employed in manufacturing the gas, coke or charcoal. Coal tar contains from 60 to 92 per cent. of bitumen. The quantity and quality of the oil contained in the tar is also variable. The quantity of non-bituminous material, such as carbon, also varies.

In street constructions a coal tar cement is used, which is the residuum from the distillation of crude coal tar. By removing a portion of the oils through distillation, the proper consistency or hardness may be obtained. The oil content of the coal tar controls the temperature at which distillation takes place.

In the selection of coal tar to be used in street constructions, one should be acquainted with its purity, chemical composition and physical characteristics. In the use of coal tar care must be exercised in the selection and compounding of the other materials, as explained in the discussion of tar-macadam or bitulathic pavements.

In this state, coal tar is produced as a by-product in the manufacture of charcoal, chiefly by the Sligo Furnace Co., at Sligo.

DRAIN TILE.

Any clay of moderate plasticity may be used in the manufacture of drain tile. The color of the tile depends chiefly upon the iron, lime and magnesia content. Drain tile should be porous, not vitrified. However, they should be well burned and strong enough to withstand rough handling and severe freezing.

The following is the composition of several clays, from which a good quality of drain tile is manufactured.

THE BURLINGTON BRICK AND TILE COMPANY, BURLINGTON, WISCONSIN.

H ₂ O & C	17.04
SiO ₂	43.64
Al ₂ O ₃	14.37
Fe ₂ O ₃	4.40
CaO	10.84
MgO	5.19
Na ₂ O	0.36
K ₂ O	3.76
Total	100.04

SPRINGFIELD BRICK AND TILE COMPANY, SPRINGFIELD, ILLINOIS.

H ₂ O & C	5.81
SiO ₂	70.15
Al ₂ O ₃	13.98
Fe ₂ O ₃	4.80
CaO	1.18
MgO	1.03
Na ₂ O	1.34
K ₂ O	1.94
TiO ₂	0.40
Total	100.59

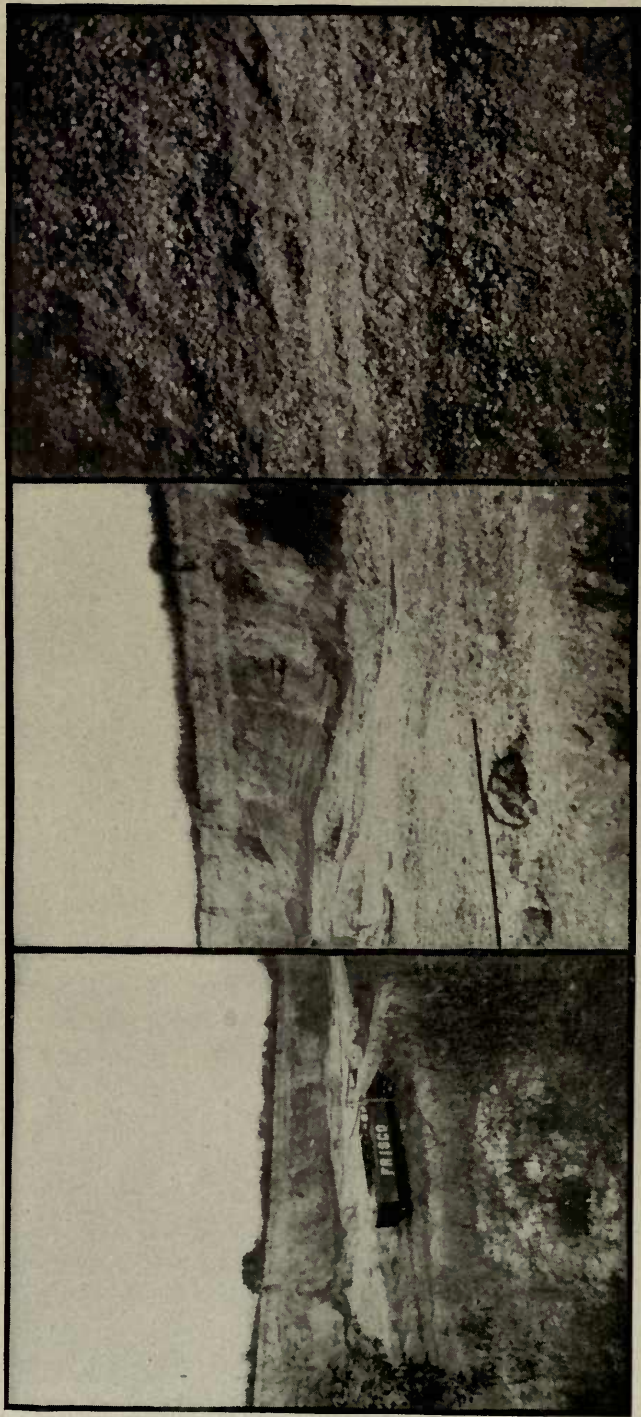
W. H. EVENS, WAYNESBURG, OHIO.

H ₂ O	1.03
SiO ₂	68.89
Al ₂ O ₃	15.89
Combined water	7.07
Fe ₂ O ₃	0.86
CaO	0.59
MgO	0.66
K ₂ O	2.23
Na ₂ O	0.29
TiO ₂	0.16

Drain tile are very important to remove the water from exceptionally wet portions of a road. In some instances a line of tile laid through the center of a road, and several feet below the surface, will remove the surplus water and keep the pavement permanently dry. Cross drains are in some places equally as efficient. Drains should be very carefully laid, otherwise they will be of very little service. Tile drainage in road construction has been too little appreciated, and should be given greater attention, especially along the country highways.

There is an abundance of clay in this state suitable for the manufacture of drain tile. A list of drain tile factories is given in another place.





VIEWS OF GRAVEL BANK SOUTH OF PACIFIC, MO

GLASS.

In some of the European countries glass blocks have been manufactured and used for street paving. For a great many years glass has been used in sidewalk constructions, and in this capacity it has been very satisfactory. In strength and hardness it equals much of the stone now being used in our larger cities. Pavements constructed out of glass blocks are said to be quieter than those built out of stone. Glass used for paving or sidewalks must be tough and strong.

The two essential ingredients of glass are silica and lime. These are found in Missouri in unlimited quantities and in close proximity to each other. If glass blocks can be economically manufactured in European countries, there is no reason why a similar industry could not be established in Missouri. We believe that experimentation along this line might result in the production of a very desirable material for street paving.

GRAVEL.

This term has a wide application to any deposit of pebbles or angular fragments of stone brought together by the action of either water or ice. In Missouri the word gravel is also applied to residual deposits of flint and clay, in which the former is greatly predominant. The fragments of which a deposit of gravel is composed may be rounded, angular or semi-angular, depending upon the distance which they have been transported by water or ice. The fragments may be any of the numerous varieties of rock, such as granite, limestone, quartzite, etc. In the southern part of Missouri the deposits of gravel consist chiefly of chert or flint, which has been derived from the limestone formations. In close proximity to the St. Francois mountains there are deposits of gravel which consist chiefly of granite and rhyolite. As the distance from the St. Francois mountains increases, the percentage of fragments of igneous rocks decreases, the gravel being mainly flint. The northern part of the State is covered with a mantle of glacial drift, through which is distributed fragments of rock collected at various places between Missouri and northeastern Canada. In some places the glacial drift consists of sand and gravel, although over a greater part of the area in Missouri the drift contains only occasional boulders and pebbles. Throughout the Ozark region the ridges and hills are covered with a mantle of residual material, some of which is chiefly angular fragments of flint embedded in a matrix of clay. This residual deposit is called hardpan, and in case

the percentage of clay is not too great, it forms an extremely hard compact mass when used on the surface of a road.

From the above it will be noted that there are three sources of gravel in this State. (1) The rivers and streams; (2) glacial deposits, and (3) residual deposits. The gravel of the river and stream deposits is usually smoother and rounder than that of either the glacial or residual deposits. It also contains less clay and sand, being better assorted than either of the other two. The glacial gravels are often unassorted, and are usually embedded in a matrix of clay and sand. The percentage of clay and soil mixed with the glacial gravel is usually so great as to make it undesirable for road improvements. Wherever the clay exceeds 30 per cent, the gravel is considered undesirable. In some instances deposits have been formed from glacial streams, and in such cases the pebbles have been brought together and separated from the clay and sand. Frequently the deposits are too clean to be well suited for road improvements. In such cases, the addition of clay is thought to be very desirable.

The residual deposits, especially those of the Ozark region, consist of angular fragments of flint firmly embedded in a clay matrix. Gravel deposits of this character, provided they contain not to exceed 20 per cent of clay, are very desirable materials for improving the country roads.

In the southern part of the State the granite has frequently been decomposed to a considerable depth, furnishing what might be termed a gravel. The rock has disintegrated so as to fall into small irregular pieces, consisting chiefly of decomposing feldspar and quartz. This material is exceptionally well adapted for improving highways, and should be used more extensively than at present.

In the mining districts of St. Francois, Madison, Lawrence, Jasper and Newton counties, there is produced, through the milling operations, a finely crushed product known as chat. In Jasper, Newton and Lawrence counties the chat is chiefly flint, while in St. Francois and Madison counties it is dolomite. This material is especially valuable for the improvement of country roads, as well as the residence streets in towns, cities and villages. It is essentially an artificial gravel, resembling, in most respects, the finely crushed stone used for macadam pavements.

BURNT CLAY BALLAST (GUMBO).

The term gumbo is applied both to the ballast and the clay from which the ballast is burned. Up to the present time it has

been used almost exclusively for railroad ballast. In some localities, where there are no quarries or gravel beds, it has been used as a road metal and for sidewalks. In some of the northern counties of this State it is thought that gumbo ballast might be used to advantage in the improvement of the streets and country roads.

The character of the clay used for the manufacture of gumbo ballast is shown by the following analyses:*

Silica	55.0 to 65.0
Alumina	15.0 to 20.0
Combined water	6.0 to 10.0
Iron Sesquioxide	5.0 to 7.0
Lime	1.0 to 3.0
Magnesia	0.5 to 2.0
Alkalies	2.5 to 4.0

Gumbo may be burned with or without kilns and at a low heat. It is burned to incipient vitrification, not being supplied with sufficient heat to result in complete vitrification or slagging.

The ballast now being manufactured is a reddish, gravelly material, the particles varying in size from a coarse sand to a large sized walnut. The particles have a very irregular angular shape and resemble pieces of hard burned porous brick.

I do not know of any locality where gumbo is now being burned in this State for use on highways. The railroads in the northern part of the State are using this material very extensively for ballast. There is an abundance of clay in the northern part of Missouri suitable for the manufacture of gumbo, and its wide distribution over areas where suitable stone cannot be found makes this an important source of materials for paving streets and country roads.

As near as can be learned, the first clay used for ballast by the Atchison, Topeka & Santa Fe Railway Company was burned in 1893 at Sheridan River Bottom, one and a half miles west of Biddle. Since that time 100,000 yards have been burned one and a half miles east of Norborne, and 50,000 yards west of Rothville. The Chicago, Burlington & Quincy Railway Company, has manufactured burnt clay ballast at the following points in Missouri: Seeburger, Chariton, Laclede, Kearney, Saxton, Iatan, Bigelow and Phelps. The Chicago, Rock Island & Pacific has manufactured this kind of ballast at Altamont. The Chicago, Milwaukee & St. Paul Railway Company has used about 250,000 yards of burnt clay ballast during the last four years. Since 1896, the Wabash Railroad Company has manufactured burnt clay ballast at the

*"Clay Deposits of Missouri," Vol. XI, Missouri Geological Survey, page 543, H. A. Wheeler.

following places in Missouri: Clifton, Elm Point, Excello, Lock Springs and Keytesville. A large part of the burnt clay ballast used by the railroads in Missouri has been manufactured by the Davy Burnt Clay Ballast Company of Kenosha, Wisconsin, and the American Ballast Company of Chicago, Illinois.

The methods of manufacturing this material are very similar, as shown by the following quotations from those interested in its manufacture and use:

1. "A fire is started with old ties, and after this is pretty well under way, gumbo is plowed up and carried by conveyors onto the fire, coal being mixed with the gumbo. One fire of ties is, of course, sufficient, as coal is used thereafter."

2. "The common method of working this is, after the ground is located, to lay the necessary tracks to be used as a storage track for coal and other materials and afterwards as a loading track to remove the ballast after burned. Sometimes two tracks are laid. A long fire is started on the ground, generally by means of old, soft wood ties, placed end to end, three or four ties to a length. After this is well fired, coal (generally slack) is put on. This is covered with about six inches of the clay or gumbo to be burned. Following this, alternate layers of coal and clay are added, until as much ballast has been burned as needed."

3. "The ground selected is low land, and what is termed 'gumbo.' The fire is started first with wood for a distance of one-quarter to one mile in length, and a coating of fine coal is put over this and started burning. A layer of clay of about four inches is next added, and again a layer of fine coal of from one to two inches in thickness. This is continued until you have a bank from fourteen to sixteen feet in height. The clay and coal are then continued on one side of the slope of this bank in layers of one inch of coal to four or five inches of clay. The heat passing through this bank burns the clay until it is a red color, and it requires about sixty days for it to thoroughly burn. The clay and coal are piled on the bank by machinery in the shape of a derrick and movable scraper on a car, which runs on a track. The process is continued on one side of the bank for as long a time as you desire to burn ballast, and after it has been thoroughly burnt on one side, a track is laid alongside the bank and the ballast is loaded onto cars for transportation to points where it is desired to place it on the track."

4. "We find a suitable location and secure as long a strip of land as possible to enable us to get a long fire. We sometimes put

in two or more fires parallel to get sufficient length. We start these fires with old ties or wood, after which we use nothing but soft coal screenings, adding a layer of coal and a layer of clay, and burning on one side of the pit. After we have made this pit a certain width, loading can be commenced on the rear side of same, or at the point where the fire was first started. The material used is 'gumbo' or 'joint clay', found in bottom lands, and free from sand."

Burnt clay ballast has a red or reddish-brown color, and when thoroughly burnt is almost hard enough to cut glass. While burning it assumes approximately the natural shape of clay, which is often approximately cubical. In size it varies from the size of a pea to a walnut, or even larger. A yard of ballast, as manufactured by the American Ballast Company, weighs 1,700 pounds, and is said to absorb about 700 pounds of water.

The quality of the ballast depends first upon the material used. Clay is much better than gumbo, but is more expensive to burn. Second, upon the care with which the fires are kept up and the material applied. The ratio of fuel to clay varies with the clay used, and care must be exercised to secure the correct proportions. The coal supply must be constant, else the fires will go out, resulting in the production of considerable poor ballast.

It is generally conceded that the cost of the ballast in the pit depends mainly upon the cost of slack coal. Where pits are located near coal mines, the cost of coal per cubic yard of ballast ought not to be very great, provided it does not require over one ton of slack to burn three yards of ballast. The following figures give the estimated cost of manufacturing ballast, as furnished by one of the railway companies:

Contract price for burning, including cost of land.....	0.1750
Coal fuel	0.2411
Wood fuel	0.0005
Labor putting in tracks.....	0.0019
Labor taking up tracks	0.0003
Comparatively indestructible track materials partly estimated.....	0.0003
Comparatively destructible track materials partly estimated.....	0.0032
Freight cost of coal per cubic yard ballast	0.0207
Total cost per cubic yard ballast.....	0.4430

In a similar manner figures made up for other pits are as follows:

Total cost per cubic yard in pit.....	0.175
Total cost per cubic yard in pit.....	0.476
Total cost per cubic yard in pit.....	0.35
Total cost per cubic yard in pit.....	0.457
Total cost per cubic yard in pit.....	0.884
Total cost per cubic yard in pit.....	0.343
Average cost per cubic yard in pit.....	0.4475

It may be safe to add that the cost of burnt clay ballast should not exceed 45 or 50 cents per cubic yard in the pit. Under favorable circumstances it can be manufactured at a much less cost.

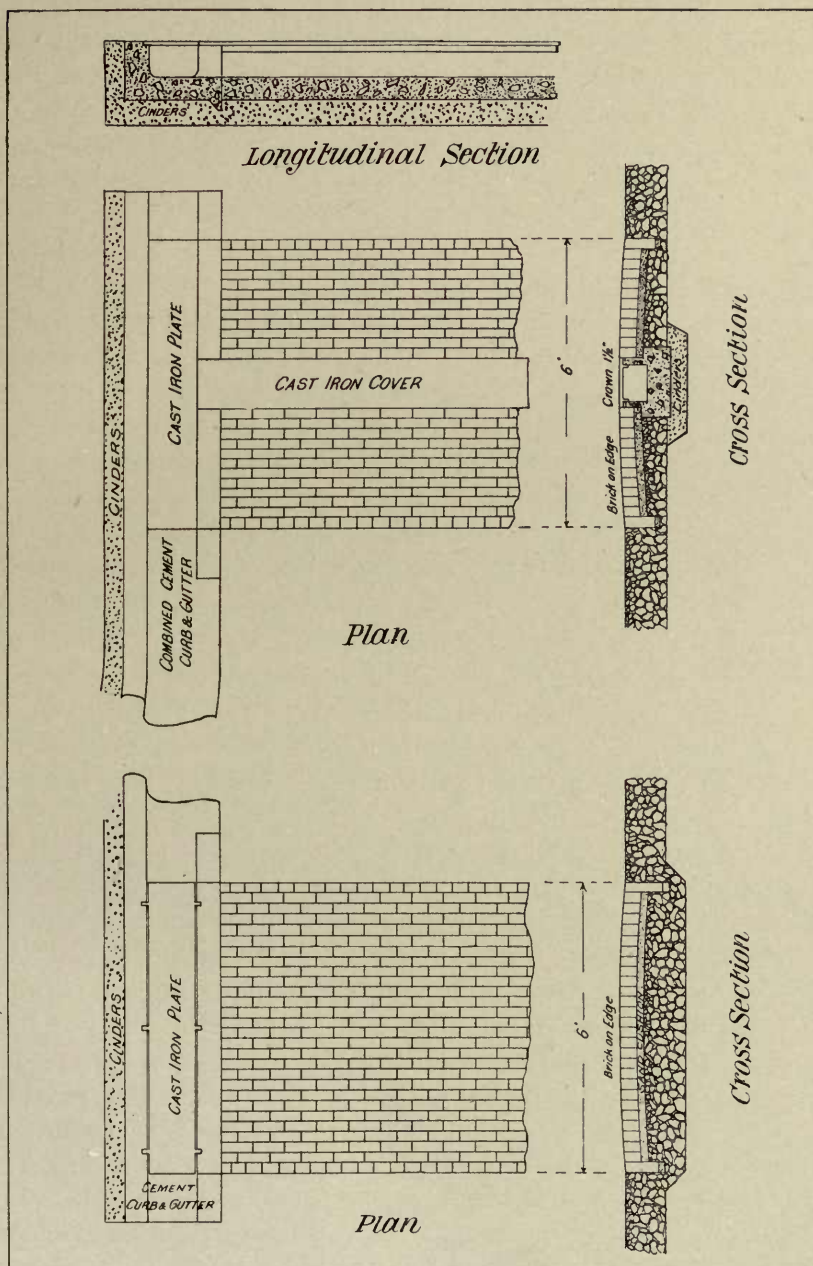
The largest users of burnt clay for railroad ballast testify as to its excellence for this purpose, especially in territory where gravel is not available, or crushed stone is so expensive as to make it undesirable.

With regard to the use of burnt clay as a material for improving our highways, where crushed stone is too costly and gravel not obtainable, an engineer for one of the railway companies says: "None of the material which we have burned would make a very good road bed for a highway, as the ordinary tires would cut down into it, and wear it out too fast." In the same communication he infers that the material which they have burned has not been of the highest grade. The engineer for another of the railway companies using large quantities of burnt clay says that, although he does not believe it to be suitable for highways, on account of the traffic grinding it into powder, which will make mud, he thinks that it would be a great improvement over the natural soil.

The American Ballast Company, one of the largest manufacturers of burnt clay ballast, expresses the opinion that suitable burnt clay could be manufactured, and that "this material, properly burned, would make an excellent highway and keep the road dry." They observe that "the material is easily handled, and highways could be easily repaired by working over this material; that there is no material that would mix better with sticky mud, making a solid road bed, than burnt clay."

IRON.

Culverts, pipes, catch basin covers, aprons, and sometimes sewers, are built out of iron. Gas and water mains are built almost exclusively out of iron pipes. Turnpike culverts are also sometimes constructed out of iron. The use of iron, however, is expensive, since it must be very strong wrought iron in order to sustain heavy traffic. Aprons and gutter covers on the approaches to sidewalks, and steps leading up to public buildings, guardrails, hitching posts and the outer edge of curbing next to the sidewalk, are frequently built out of iron. The use of iron to protect curbing in places where there is heavy traffic is a wise precaution. In many ways iron is very useful in making permanent street improvements, and in some cases, such as gas pipes and water mains, there is no suitable substitute.



Cross Walks and Gutters with Iron Covers and
Cross Drain.



OIL OR PETROLEUM.

The only use for petroleum or crude oil is in the construction of asphalt and bituminous macadam pavements. In California and other states petroleum is sprinkled along the streets and railroads to lay the dust. The practicability of using crude petroleum for this purpose depends almost entirely upon its cost. The disagreeable odor combined with its liability to soil garments render the use of petroleum objectionable.

SAND.

Sand, which is used for commercial purposes, varies quite widely in its mineralogical composition, depending upon its source. Sand is always a product of rock disintegration, being derived originally from quartzose varieties of igneous rocks. When pure, it consists of grains of quartz, known commercially as silica (SiO_2). It is one of the most stable minerals of which we have any knowledge, remaining unchanged after all the associated minerals have been decomposed. The commercial product often contains, besides quartz, small percentages of feldspar, mica, calcite, dolomite, hornblende, kaolinite and other minerals. As a deposit from water, it has been transported a greater or less distance, as a result of which the individuals are more or less rounded. The deposition from moving water also results in assorting the particles according to size, on account of which we find deposits of coarse and fine grained sand. Some deposits of sand consist of alternating layers of coarse and fine grains.

The value of sand depends chiefly upon its composition, and upon the size and shape of its grains. Considerable percentages of calcite, dolomite, hornblende and iron oxide are considered objectionable. These minerals are softer than quartz, and decompose more rapidly. In any particular deposit of sand, the grains may be well assorted, or they may consist of grains which vary considerably in size. Sand which consists of grains of heterogeneous sizes weighs more than sand in which the grains are of uniform size. For this reason, sand consisting of grains of miscellaneous sizes is more desirable for most purposes than sand in which the grains are of uniform size. Sand which has the smallest percentage of voids is sometimes obtained by mixing that from different banks in which the grains are of different sizes. In concrete, or other cement constructions, sand having sharp angular outlines gives the most satisfactory results.

Most of the sand used in this State is obtained from the rivers and streams by dredging. The Mississippi, Missouri, Meramec, Gasconade and Osage rivers deposit each year great quantities of sand in the shape of bars, which constitute an almost unlimited supply for use in the cities and towns adjacent to these streams. Within a radius of 50 miles of St. Louis there are numerous exposures of St. Peters sandstone, from which a high grade of sand can be obtained. The disintegration of the sandstone, which occurs in irregular areas throughout the Ozark region, also furnishes an unlimited quantity of sand for commercial purposes. The semi-indurated sandstone of the Cambro-Ordovician formations in the Ozark region is easily quarried and pulverized.

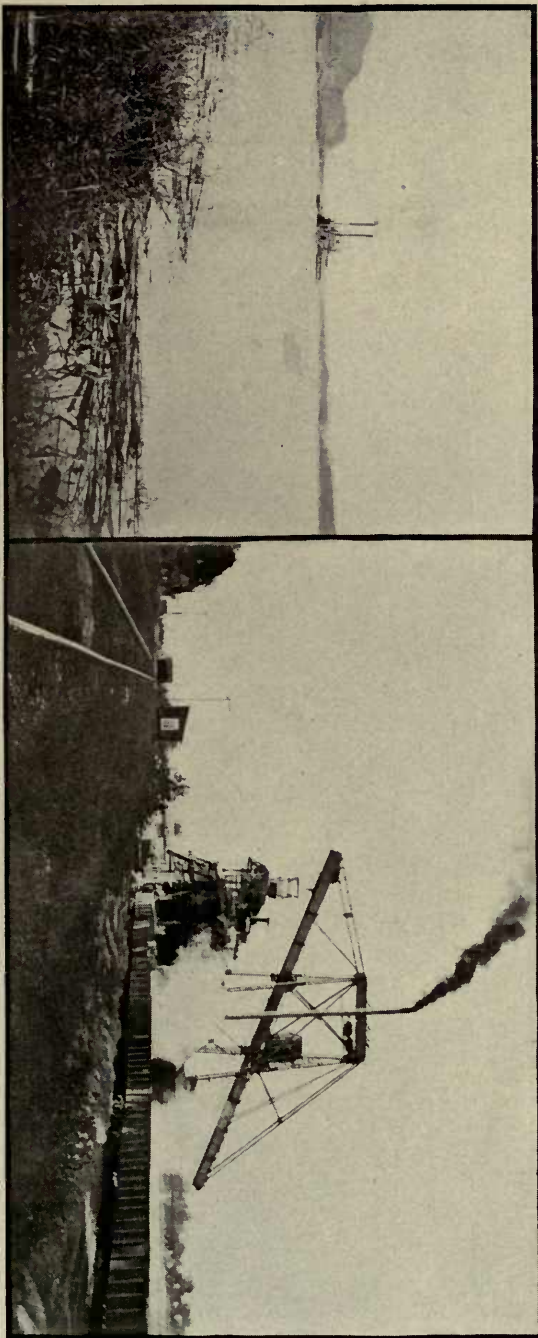
Great quantities of the St. Peters sandstone is used in the manufacture of glass. This sandstone is exceptionally pure, containing as high as 98 to 99 per cent of silica. In the northern part of the State there is an abundance of sandstone, forming a part of the Coal Measures formations, from the disintegration of which sand may be obtained for commercial purposes. The sand in that section of the State is, as a rule, impure, and can only be used in masonry constructions. It is suitable, however, for use with cement in concrete constructions, granolithic walks and cement curb and gutter.

In the southeastern part of the State, associated with the igneous rocks, are small veins of quartzite. A very high grade of sharp sand might be obtained from this source by crushing and washing. Sand of this quality, however, can be used most advantageously in the pottery industries, on account of the expense attached to its production.

The fine dust produced in crushing granite and rhyolite is sometimes sold as sand. This is well suited for use in masonry constructions, and can be substituted anywhere for river or stream sand.

SHELLS.

Along the Mississippi river, especially in the northern part of the State, great quantities of bivalves are caught each year, and their shells used in the manufacture of pearl buttons. Hundreds of tons of these shells are dredged from the river each year, searched for pearls and sold to the button factories. Only the thickest and best part of the shell is used by the manufacturers, the remainder being thrown away as valueless. These shells are hard and tough, and fairly well suited for improving the roads.



PUMPING SAND AND GRAVEL FROM MISSISSIPPI RIVER AT HANNIBAL, MO.

UNLOADING GRAVEL FROM BARGE, HANNIBAL, MO.



Any city or town in which one of these factories is located might use these shells for improving the streets. In Wisconsin several towns are using the shells for this purpose, and they are reported to be very satisfactory. In using the shells, they should be spread over the surface three or four inches deep and rolled, as in the case of a macadam pavement.

Attention might be called to the fact that in Florida, and other sea coast states, some of the finest pavements are built out of shells, and there appears to be no reason why Missouri cities, having a supply on hand, should not use them in this manner.

SLAG.

Slag is a scoriaceous by-product of smelters and blast furnaces. It usually has a porous or semi-porous texture, although the composition depends largely upon the kind of ore and flux. The slag from the lead furnaces in this State has a hard dense body, differing in that respect from the slag from iron furnaces. If treated with cold water, the hard dense blocks might be broken up so as to make the product more suitable for use on the roads.

Chemically, slag consists of varying percentages of alumina, silica, calcium carbonate and iron. When drawn from the furnace it is sometimes allowed to cool and harden, after which it is broken into small fragments with a mallet or sledge. In other cases, water is poured upon it from a nozzle, completely disintegrating it and forming a coarse granular mass, resembling sand.

Slag is frequently used in the same manner as crushed stone in the construction of pavements. Coarse fragments are spread on the bottom and finer slag screenings on the top. There is a considerable difference in the serviceability of slag roads, possibly due to the methods of construction, but more probably as a result of differences in the composition of the slag. In any case, this is an important source of material for improving the highways. In the construction of granolithic or granitoid walks slag may be used in the place of cinders, and for this purpose it is eminently satisfactory.

It is possible to mold molten slag into paving blocks, and some time this furnace by-product may be used in this manner.

VITRIFIED CLAY SEWER PIPE.

The manufacture of sewer pipe out of cement has come into such prominence during the last few years as to require the appli-

cation of a more definite term to that which is manufactured out of clay. For this reason it is now spoken of as "vitrified sewer pipe," in distinction from "cement sewer pipe."

The following are analyses of clays used in the manufacture of vitrified sewer pipe from two localities:

	No. I*	No. II**
SiO ₂	65.15	58.38
Al ₂ O ₃	15.20	20.80
H ₂ O.....		7.53
Fe ₂ O ₃	6.16	5.78
CuO.....	3.50	0.44
MgO.....	1.57	1.57
K ₂ O.....	5.17	4.68
Nb ₂ O.....		0.34
Total.....	97.28	99.61

*"Clay Industries of New York," Ries, Albany, 1885.

**"Clay Worker", May, 1894, Orton.

No. 1 is the analysis of a clay from a sewer pipe plant in New York, while No. II is the analysis of a clay from an Ohio factory. These clays differ considerably in composition, and will serve to illustrate the range in composition of clays which may be handled in such a manner as to make a first-class vitrified sewer pipe.

Sewer pipe should possess three qualities, the absence of any one of which makes an imperfect and inferior product, namely: (1) strength, (2) smoothness of interior, (3) imperviousness. Sewer pipe should be sufficiently strong to withstand not only the pressure of the dirt filling deep trenches, but also that of steam rollers and other heavy bodies which may pass over the surface. The strength of a pipe may be best obtained by placing a length on two end supports and loading it at the center. Its ability to withstand vertical pressure is measured by the weight required to break the pipe. Mr. F. A. Barbour, in an article published in the Journal of the Association of Engineering Societies, December, 1897, says that he found, by experimenting, that a 6-inch standard pipe would sustain a maximum load of 2,800 pounds per running foot. Additional experiments showed that an 18-inch pipe in a 9-foot trench is ordinarily called upon to sustain a weight of 325 pounds per square foot. An 18-inch standard pipe, having a strength of 1,860 pounds per square foot, has a factor of safety of 5. The factor of safety depends in a measure upon the kind of material with which the trench is filled. It has been shown that sand and

gravel, with a coefficient of friction of 0.69, will transmit 0.31 of its own weight, while wet clay, with a coefficient of friction of 0.35, will transmit 0.65 of its weight to the pipe underneath. The experiments conducted by Mr. Barbour indicate that the load transmitted far underground by steam rollers is about the same per cent. as in the case of earth filling. Thus, if a steam roller exerts a pressure of 2,500 pounds per square foot on the surface of a clay trench, this will add 1,625 pounds per square foot to the pressure on an 18-inch pipe at the depth referred to above. The total pressure which such a pipe will be called upon to sustain will therefore be 2,200 pounds. In such a case a pipe of double standard strength, 2,800 pounds per square foot will be required.

A smooth interior surface is required in order to allow a free passage of water. A smooth surface also prevents the accumulation of debris, which is liable to clog the passage. An impervious body is required in order that the water will not soak through or saturate the pipe. Simple glossiness of the surface does not indicate imperviousness. The body of a clay pipe must be vitrified in order to produce this quality.

Complete vitrification not only renders the pipe impervious, but also adds to its strength, and is therefore an important consideration, which must not be overlooked. The exterior of a pipe should be smooth and free from blisters, and special care should be taken to use only such sections as are not cracked or broken.

There are a number of factories in Missouri manufacturing an excellent grade of sewer pipe, which can be obtained in almost any required dimension. St. Louis, Kansas City and Deepwater are the centers of sewer pipe production in this State. The following is a list of the factories which are manufacturing sewer pipe:

F. X. Blanck, Boonville; W. S. Dickey Clay Manufacturing Co., Kansas City and Deepwater; Greer Bros., Mt. Vernon; Aug. Blanck, California; Blackmer & Post Pipe Co., St. Louis; Laclede Fire Brick Manufacturing Co., St. Louis; and Evens & Howard Fire Brick Co., St. Louis.

STONE.

The most abundant, cheapest and most widely used material for street construction is stone. This is perhaps the most important material for road construction and the one to which the people in Missouri must turn for the improvement of most of their highways. Stone occurs throughout the State in great variety and differs as widely in quality as asphalt, coal tar or any of the other

materials previously described. Many people have a very meager knowledge of the condition and physical qualities of stone, and for this reason it is thought best at this place to discuss this material more in detail than those in the preceding part of the chapter.

On the basis of their origin, rocks are divided into three classes, known as (1) igneous, (2) sedimentary, (3) metamorphic. Igneous rocks are formed through the solidification of molten magma. Sedimentary rocks are formed through mechanical or chemical deposition from water. They have been derived from older igneous and sedimentary rocks, and consist of gravel, sand, clay and lime. When deposited they are usually soft, being consolidated afterwards through cementation and pressure. Metamorphic rocks are altered igneous and sedimentary rocks in which the original structures and textures have been almost, if not quite, obliterated.

Igneous rocks usually have a complex mineralogical and chemical composition, frequently consisting of ten or twelve different minerals, of which two or three common species make up the greater part. Sedimentary rocks usually have a much simpler composition, consisting essentially of one or two minerals, with several less important varieties, in greatly subordinate amounts. The individual minerals composing igneous rocks are usually closely interlocking, while the individuals composing sedimentary rocks are usually bound together simply by material which has partly filled the interstices, forming a sort of net work. The size, arrangement and manner of contact of individual grains are usually very different in an igneous than in a sedimentary rock. On account of this, the igneous rocks are usually stronger and more durable, even though they may be very similar in mineralogical composition. The metamorphic rocks resemble in texture the igneous rocks, although they frequently exhibit structures which render them less durable than rocks of the igneous class.

In order to select intelligently the stone to be used in street constructions, one should be familiar with the mineralogical composition and texture of the different rocks from which a selection is to be made. By mineralogical composition is meant the minerals of which the rock is composed. By texture is meant the size, arrangement and manner of contact of the individual grains composing the rock. From the above it will be seen that an intimate and thorough knowledge of the common rock-forming minerals is very essential. One should also be acquainted with the effect which various combinations of minerals and different textures and struc-

tures may have upon the strength and durability of the stone. It frequently requires expert knowledge in order to determine these, and the use of a microscope is very important for this purpose.

The important rock-forming minerals and groups of minerals of which one should have a knowledge are, amphibole, calcite, chlorite, dolomite, feldspar, hematite, limonite, magnetite, mica, olivine, pyroxene and pyrite. These minerals have characteristic physical properties which distinguish them from one another. They may be recognized by their system of crystallization, specific gravity, hardness, color, luster, cleavage and streak. The physical properties which are most important in a consideration of stone as a material for street construction are size, hardness and cleavage. These, combined with the chemical composition, determine the value of the mineral as a constituent of a rock for street constructions.

The following are short descriptions of the rock-forming minerals listed above:

Quartz—Quartz is a combination of two of the most abundant known elements, silicon and oxygen, united in the form of silicon dioxide (Si O_2). It is one of the hardest of the common rock-forming minerals, being 7 in the scale of hardness. It has no ready cleavage. As a rock-forming constituent, it is generally colorless, although when found alone it is frequently brown, yellow, purple, milk white or pink. As a rock-making constituent, the individuals usually have rounded, oval or irregular outlines. When occurring alone or in a crystal aggregate, it usually has perfect crystal faces.

Among all the common rock-forming minerals, quartz is one of the most abundant. It is very hard and resists to a high degree all the agents of weathering. It is usually broken into small particles by disintegration, but at the surface of the earth it is decomposed and taken into solution very slowly.

Calcite—Calcite or calcium carbonate, more commonly known as lime or limestone, is composed of the elements calcium, carbon and oxygen combined as Ca CO_3 . The hardness of calcite is 3. Its color as a rock-forming mineral is usually white or cloudy. Sometimes the impurities which it contains impart a brown or pink color. It has a perfect cleavage in three directions, on account of which it readily breaks into small six-sided pieces, having inclined faces.

Calcite is often mistaken by inexperienced observers for quartz.

The two minerals are almost identical in color, but if the hardness of calcite (3) and that of quartz (7) are kept in mind, there will be little danger of confusing the two. The absence of cleavage in quartz also provides a means of distinguishing it from calcite.

Calcite is acted upon very readily by water containing sulphuric and carbonic acids. At or near the surface of the earth it is one of the least stable of the abundant rock-forming minerals. It makes up a large part of limestone rock, which will be considered later.

Dolomite—Dolomite is composed of calcium, magnesium, carbon and oxygen ($\text{Ca, Mg} \text{ CO}_3$). It has a hardness approaching that of calcite, being 3.5 to 4. It has as perfect a cleavage as calcite, but is acted upon less readily by dilute hydrochloric acid. Its less solubility in dilute hydrochloric acid is the usual field method of distinguishing it from calcite.

Feldspar—The term feldspar is applied to a group of minerals containing two series, under both of which are included several species. Certain of the species differ in the elements which enter into their composition, while others differ merely in the percentage of such elements. The two series of minerals are ordinarily known by the name of their most common member as orthoclase and plagioclase. Orthoclase is composed of an admixture of potassium, aluminum, silicon and oxygen, with occasionally a small percentage of sodium ($\text{K, Na}_2 \text{ Al}_2 \text{ Si}_6 \text{ O}_{16}$, (Hintze). Plagioclase contains sodium, calcium, aluminum, silicon and oxygen, and its composition is represented by one of the following or some intermediate formula: $\text{Na}_2 \text{ Al}_2 \text{ Si}_6 \text{ O}_{16}$ — $\text{Ca}_2 \text{ Al}_4 \text{ Si}_4 \text{ O}_{16}$. The two series of minerals differ in their system of crystallization as well as in their composition. The former is monoclinic and triclinic, and the latter is triclinic. Orthoclase is the characteristic mineral of one of the two major groups of igneous rocks, to be hereafter described, while plagioclase is one of the characteristic minerals of a second of these groups.

The hardness of feldspar is 6 to 6.5, being surpassed among the common minerals only by quartz. The minerals of this series have two very prominent cleavages. Feldspar occurs only occasionally in the sedimentary rocks, being an important constituent mainly of the igneous and metamorphic varieties. Next to quartz, feldspar is one of the most stable of the common rock-forming minerals. Its ready cleavages permit a freer passage of water in and through its entire mass than in the case of quartz. For this reason the molecules are slowly broken down, resulting in

a rearrangement and recombination of the elements, forming a variety of new minerals, among which are kaolin, quartz, chlorite, mica, epidote, zoosite and calcite. This process takes place so slowly, however, that it is scarcely worth attention in a consideration of stone used in street construction.

Mica—There are several varieties of mica, differing from one another, either in the elements or in the percentage of elements of which they are composed. The two most important species are muscovite and biotite. The former consists of the elements, hydrogen, potassium, aluminum, silicon and oxygen, while the latter contains, in addition to the above, magnesium and iron. The hardness of muscovite is 2.5, and that of biotite, 2.5 to 3. The chief distinguishing characteristic of mica is its easy and close cleavage. It has the appearance of being composed of very many exceedingly thin, glossy sheets piled one upon another. Both of the common varieties of mica decompose very slowly when exposed to the atmosphere. On account of its ready cleavage, mica does not unite very strongly with the adjacent minerals of the rock of which it forms a part. It is, therefore, one of the first minerals to break down, mechanically, hastening the disintegration of the rock. It occurs mainly in the igneous or metamorphic rocks, and to a less extent, in the rocks of the sedimentary series.

Amphibole—The mineral species to which this name is commonly applied consist mainly of magnesium, calcium, silicon, iron, manganese and oxygen, with or without aluminum. The two most common species are hornblende and actinolite. The hardness of these minerals is from 5 to 6, being very little less than that of feldspar. They have a very perfect cleavage, which is useful in distinguishing them from other minerals having other characteristics in common with them.

Amphibole is an essential constituent of many of the granites, and more especially of the basic series of igneous rocks. It is also abundant in many of the schists and altered sedimentaries, both of which are included under the metamorphic series. This mineral alters very slowly to a mixture of carbonates, clay, limonite and quartz.

Pyroxene—The mineral species included under the general name of pyroxene have nearly the same composition as those included in the amphibole group. The species are ordinarily composed of one or more of the elements, magnesium, calcium, iron, manganese, sodium and lithium, in combination with silicon and

oxygen, with the addition in certain of the important species of aluminum as an essential constituent. The hardness varies from 5 to 6, occasionally reaching as high as 7. Pyroxene has a perfect cleavage in two directions, as in the case of amphibole. The cleavage planes intersect at an angle of about 90° , while in amphibole they form acute and obtuse angles. This is one of the easiest methods of distinguishing the two.

The most important rock-forming member of this group is augite. This mineral is an important constituent of many of the granite gneisses, and more especially of the basic rocks. Pyroxene is slowly decomposed, altering to chlorite, calcite, iron oxide and epidote.

Chlorite—This name applies to a group of minerals composed of various combinations and proportions of magnesium, iron, manganese, aluminum, hydrogen, silicon and oxygen. The minerals of this group are very soft, having a hardness of from 2 to 2.7. Chlorite is ordinarily an alteration product of some other mineral, but may itself be decomposed into a mixture of carbonates, clay, limonite and quartz. It is a very common constituent of the class of rocks known as "greenstone."

Olivine—This name applies to a group of minerals differing from each other somewhat in composition, but being composed in general of various proportions of magnesium, calcium, iron and manganese in combination with silicon and oxygen. The hardness of these minerals ranges from 6 to 7. Olivine decomposes readily into chlorite, talc and serpentine. It is ordinarily a constituent of the more basic igneous rocks, such as diabase and gabbro.

Hematite—Hematite is composed of iron and oxygen, the composition being represented by the formula $\text{Fe}_2 \text{O}_3$. As a rock-forming constituent, it usually occurs in small grains, or as a thin film, cementing together the individual grains of the sedimentary rocks. It has an adhesive quality, which makes it especially valuable in stone used for road construction.

Pyrite—Pyrite is a combination of iron and sulphur (Fe S_2). It has a hardness of 6 to 6.5. It decomposes quite readily when exposed to the atmosphere, forming limonite and free sulphur or ferrous sulphate. Sometimes pyrite is an abundant constituent of both the igneous and sedimentary rocks. The readiness with which it decomposes, breaking down into iron oxide and sulphur, with the production of sulphuric acid, makes it destructive to limestones and other carbonaceous rocks in which it may occur.

Limonite—Limonite has the same composition as hematite,

with the exception that it contains water in addition to iron and oxygen. It is found, alike, in igneous, sedimentary and metamorphic rocks. It results mainly from the decomposition of other minerals rich in iron, such as pyrite. As a cementing material it is probably, equally as important as hematite.

Magnetite—Magnetite is ordinarily known as magnetic iron ore. It is composed of iron and oxygen ($\text{Fe}_3 \text{O}_4$). It has a hardness of 5.5 to 6.5. It is a very common constituent of igneous and metamorphic rocks, being usually disseminated in the form of grains and crystals. It alters slowly to a yellowish brown limonite.*

ROCKS.

Igneous Rocks—As a rule, igneous rocks consist of two or three essential constituents and a number of minerals of less abundance, known as accessory constituents. There are a great many varieties of igneous rocks, each having a separate name, but the ones which are most abundant in Missouri are granite, rhyolite and diabase (greenstone, or trap rock.)

Granite consists mainly of quartz and orthoclase (feldspar), with mica and hornblende as subordinate constituents.

Rhyolite is a rock having a fine, dense groundmass, in which occur large and small individuals of quartz and feldspar. This rock is commonly known as porphory on account of its porphyritic texture.

Diabase is a rock composed mainly of plagioclase (feldspar), amphibole, pyroxene, olivine and mica. In some instances this rock contains a small amount of quartz. The rocks which are known as diabase in this State belong to several allied species. They have a dark green or grayish green color, on account of which they are called greenstone or trap rock. The igneous rocks vary considerably in texture, some being coarse and others fine grained. As a rule, the individuals have irregular outlines and interlock in a very intricate manner.

The strength and durability of these rocks are in a large measure determined by the size of the individual grains and their relations to one another. The individual grains of diabase penetrate each other, giving a peculiarly compact texture, which imparts great strength and toughness to the rock. This texture also accounts for the cubical shape of the pieces which are obtained when

*These descriptions of minerals are copied from "Highway Construction," Bul. No. X Wis. Geol. & Nat. History Survey, pages 43-47.

the stone is crushed. The minerals of which granite is composed are harder than those of greenstone. They also have less cleavage and are not so complexly interlocking. The product resulting from the disintegration of granite does not furnish as strong a bond as that from greenstone. Apparently, the pulverized greenstone, or trap rock, has greater plasticity than that from granite. This accounts, in part at least, for its greater bonding capacity.

Igneous rocks may possess structures on account of which their value for road construction is increased or decreased. These structures are known as flowage, cleavage, fissility, schistosity and jointing. All of these structures, with one exception, result from a parallel arrangement of mineral particles brought about mainly by pressure and heat after the rock was formed. The presence of a very fine cleavage, fissility or schistosity is usually undesirable, since a rock possessing these structures will not crush into the cubical pieces most desirable for road construction. The jointing planes are usually helpful in quarrying the stone, in so much as they obviate the necessity of heavy blasting to loosen the blocks from the quarry.

The St. Francois mountains, occurring in the southeastern part of this State, contain unlimited quantities of granite and rhyolite, as well as small deposits of diabase. Many of these areas are close to the railroad, and therefore constitute a valuable source of materials for street paving.

Sedimentary Rocks—A sedimentary rock is usually composed of one essential constituent, from which it derives its name, and several subordinate, accessory constituents. The principal sedimentary rocks are conglomerate, sandstone, shale and limestone. These are usually qualified by the name of the most important accessory constituent.

A conglomerate is made up of roundish or sub-angular fragments, usually bound together with clay and sand, which fill the interstices. This is a very unimportant variety of stone in street paving. As a rule, it does not occur in sufficient quantity to be quarried or otherwise exploited.

Sandstone consists mainly of roundish or sub-angular grains of sand cemented together with silica, calcite or iron oxide. Some sandstones have been so completely recemented with silica as to almost obliterate the shape of the original grains. Such sandstones are known as quartzite, and belong to the metamorphic series. Sandstone which is cemented with silica is one of the most durable of rocks, although it is brittle, often possessing a splintery fracture

and having little or no bonding capacity. A sandstone may be cemented with calcite, in which case it is known as a calcareous sandstone. Frequently, iron oxide, either hematite or limonite, is the bonding constituent. Such a sandstone is usually stronger than one that is bonded with calcite. Clay, mica and glauconite frequently occur as accessory constituents, and when present in considerable quantity, have a tendency to weaken the stone.

Sandstones do not have the intricately interlocking texture exhibited by the igneous rocks. They also have a much lower crushing strength, although composed of the hardest of the common minerals.

Sandstones are used for paving blocks, curbs, sidewalks, etc., but seldom, except in the form of quartzite, do they enter into the construction of macadam pavements. Sandstone possesses structures similar to those in the igneous rocks. Whether or not these structures prove injurious, depends upon the purpose for which stone is used.

Shale is formed from mud and silt deposited in the deeper water of the ocean beyond the zone where sand accumulates. It is composed mainly of kaolin and quartz. After the process of consolidation and hardening, which goes on within the crust of the earth, shale is frequently changed to slate. When thus altered, it becomes a metamorphic rock, and for constructional purposes is of greater value than the shale. Shale is used for the manufacture of brick, tile and vitrified clay sewer pipe, all of which are used in road constructions. In some sections of the State, where roads are very sandy, the addition of shale very greatly improves their value. A very plastic clay, when broken down and wetted, is valuable for surfacing sandy roads. A shale which is mixed with sand is preferable to artificial mixtures for the temporary improvements of most roads.

Limestone consists mainly of calcium carbonate. Dolomite is a variety of limestone in which there are almost equal proportions of calcium carbonate and magnesium carbonate. Limestones frequently contain sand, clay, bitumen or graphite, on account of which they are given qualifying names, such as arenaceous limestone, bituminous limestone, etc.

Limestone differs in texture from sandstone in that the individuals are usually more firmly cemented and often interlocking. The texture often resembles that of an igneous rock. Acids act upon limestones more readily than upon most other rocks. Water carrying carbon dioxide and sulphuric or other acids will take cal-

cium carbonate into solution very readily. Dolomite is less soluble in hydrochloric acid than limestone, and, under ordinary atmospheric conditions, is stronger and more stable. Limestone and dolomite may possess all of the structures found in other sedimentary rocks, such as bedding, cleavage, jointing, etc.

The greater part of the Ozark region is underlain with the Cambro-Ordovician dolomites. Everywhere along the stream channels there are exposures of dolomite. Some of the rock is hard and durable, being well adapted for the improvement of the rural highways. On the other hand, many of the beds contain rock which is soft and unsuited for this purpose. Throughout the western part of the State, and north of the Missouri river, with the exception of those areas underlain by the Des Moines or Lower Coal Measure strata, there are numerous outcrops of limestone. South of the Missouri river, in the western part of the State, the Mississippian contains numerous exposed ledges of limestone. This stone is not as strong or durable as the dolomites of the Cambro-Ordovician. The best limestone, however, is much preferable to the surface soil which covers those sections of the State.

Metamorphic Rocks—There are very few rocks in this State which might be called metamorphic. At Pilot Knob there is a small area of quartzite, and in other sections of the State the sandstones of the Cambro-Ordovician have been sufficiently solidified to be spoken of as quartzite. Some of the limestones in the southeastern part of the State have been so modified by the introduction of calcium carbonate as to form beds of marble. These, however, are exceptional, and are usually associated with dolomite, which is much superior for road construction.

WOODEN BLOCKS.

Two kinds of wooden blocks have been used in paving the streets in some of our cities. The most common is the cylindrical cedar block, which has been used both for paving and for sidewalks. These blocks have a diameter of from 5 to 8 inches, and are from 6 to 8 inches in depth. In Wisconsin and other northern states the cedar block pavement was used very extensively in the early days. The pavement is very unsanitary, wears unevenly, and altogether it is not desirable. Wherever such pavements have been constructed, they are being replaced with asphalt, macadam, brick or stone block.

In some of our cities the rectangular, creosoted, long-leaved yellow pine block is still being used for paving. Where care is ex-

exercised in the selection of the wood, the blocks are laid on a concrete instead of a board foundation, and the joints are filled with cement grouting, the pavement is fairly satisfactory. There are several companies today laying wooden block pavements, claiming that they have a process of treating the blocks by which they are made impervious to water. As far as our experience goes, we have never observed a wooden pavement which does not lose its imperviousness after four or five years of wear. When this takes place, the blocks swell with each rain, distorting and cracking the pavement. Decay follows, and soon the blocks must be replaced with others. Nevertheless, the new wooden block is far superior to the old, and in some places it seems to be the best pavement to construct.

In the early history of our country, logs and planks were used to improve sandy, marshy roads. The corduroy road is well known to most of the earlier settlers. It consists of short logs laid crosswise of the road to prevent the horses and vehicles from sinking into the mud. It was a very excellent expedient, and might be used to advantage in some sections of Missouri today. The plank road was also a common construction in the early history of this country. In this case boards two inches thick were laid on stringers, crosswise of the road. At present, steep slopes on sandy roads are frequently improved in this way.

Brush, shavings, saw dust and straw are all used more or less in the improvement of sandy or muddy roads. These materials are used as temporary expedients, and they are in no sense permanent improvements.

Foundations to pavements, curbing, catch basins and all other street constructions which were formerly built out of wood, are now being constructed out of more permanent materials, such as brick or concrete.

CHAPTER III.

METHODS OF CONSTRUCTING DIFFERENT KINDS OF PAVEMENTS, SIDEWALKS, CURBS AND GUTTERS.

PERMANENT GRADE.

The first consideration in the construction of a pavement is the establishment of a permanent grade. This should depend chiefly upon the location of the street and the kind of traffic which it will be called upon to sustain. The grade should not be made to conform to the kind of pavement, but the kind of pavement should be made to conform to the grade. The laying of sewers, water pipes, gas mains and electrical conduits, and the grading of the streets, should precede the construction of the pavement. All excavations below the subgrade of the street should be filled and thoroughly compacted with sand, gravel and soil, which is free from organic matter. All filling should be thoroughly settled before the foundation of the pavement is laid. The addition of water to the filling assists very greatly in compacting it. Failure to observe any of these precautions may result in subsequent injury to the pavement.

It is doubtful policy to reduce all of the streets to a uniform level. Cities that are built on hilly ground lose much of their beauty by removing the undulations of the surface by reducing the grade. It is well enough to level off the ground in the business portions of a city, but in the residence districts such an operation destroys in a large measure the picturesqueness and beauty of the city. It may be more difficult to haul heavy loads over such thoroughfares, and wheelmen may be obliged to dismount and walk up an occasional incline, but these factors should not be considered alone in establishing street grades. It is possible to lessen the grades by laying out the streets in graceful curves over the hills and through the hollows. Such a proceeding will improve the beauty of the place and eliminate, in a large measure, the objections on account of steep grades. After a road has once been plat-
ted and the grade established, it can usually be changed only with difficulty. For this reason the greatest discretion should be used in platting and establishing the grades of streets.

In the case of country highways, the commercial aspect should,

in most cases, precede the aesthetic. Steep grades should always be avoided, if possible, either by excavation or by laying out the road around the base of the elevation. In many instances I have observed roads, which were laid out through almost level valleys, ending abruptly at the base of a steep hill. Instead of bringing all the "climb" in one place, it should have been distributed along the road. The load that can be hauled over such a road is limited to the load that can be pulled up the hill.)

The tendency in this State today is to lay out all roads along section lines, without regard to the topography of the country. They do not follow the path of least resistance, but of steepest grades. Attempts are also made to shift the roads from the bottom lands onto the hillsides, in order to preserve all tillable lands.

In the matter of laying out roads and establishing grades, there must be a change which will be almost revolutionary before we can have good highways.

Considered in its vertical dimension, the construction of a pavement should include a consideration of the subgrade, foundation, cushion and surface or superstructure. These will be considered separately in the following pages.

SUBGRADE.

The commissioner or engineer in charge of the construction of pavements should see that all spongy, vegetable or other objectionable material is removed from the roadbed. In soft places it is frequently necessary to sink willows or brush wood in order to support the filling of sand and gravel which should constitute the subgrade. The depth to which such material should be removed depends altogether upon circumstances. Ten or twelve inches will usually suffice when replaced by coarse sand, gravel, broken stone, broken brick, slag or cinders. All of these materials are especially suitable on account of the rapidity with which they will drain away rain water which may find its way underneath the pavement. Clay and vegetable soils expand and contract greatly as a result of alternate wetting and drying, on which account they are very objectionable. When dried from a semi-saturated condition, clay often shrinks an inch and a half in a foot, linear measurement.

The subgrade should be thoroughly compacted before the foundation is laid, and, in order to secure this condition, it should be rolled with a five- or ten-ton roller. It should be made to conform to the finished grade of the pavement, except in cases where the superstructure is made thicker at the center than at the sides.

FOUNDATION.

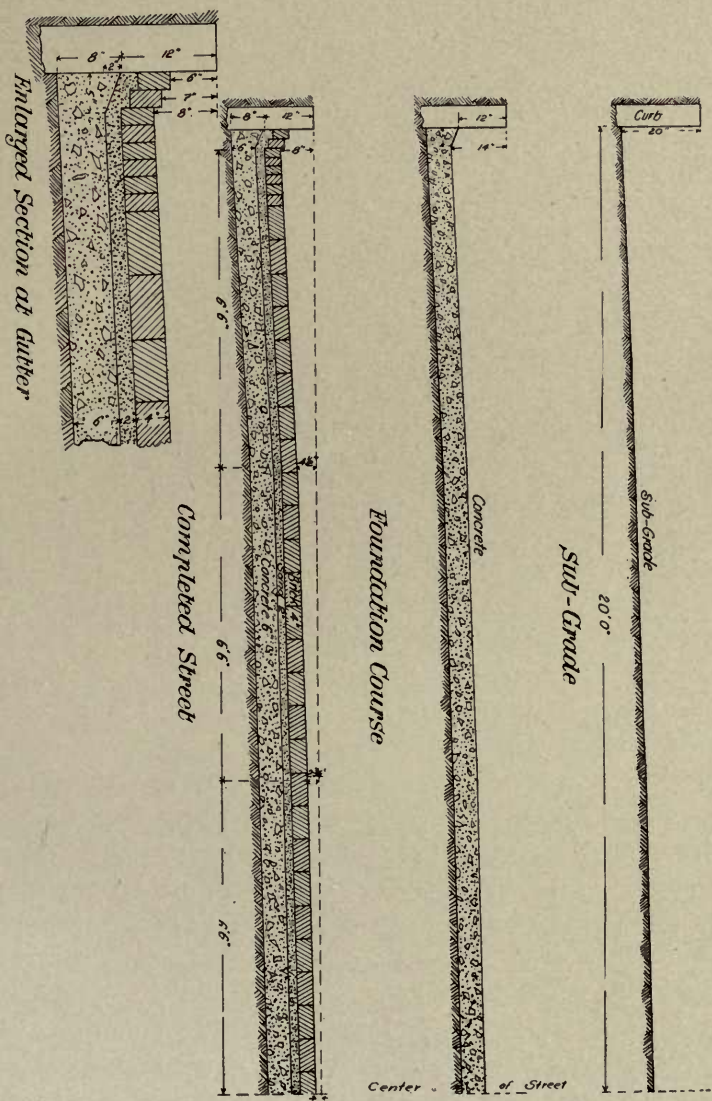
The materials which are most commonly used in the construction of foundations are sand, gravel, wood planks, broken stone, brick, slag, cinders, stone blocks and concrete.

Sand and Gravel—As a rule, these are the cheapest materials that can be used as a foundation. This depends, however, upon the distance that they have to be transported. Frequently the subsoil consists of sand and gravel, in which case the superstructure is laid directly upon the subsoil without the intervention of other materials. A sand and gravel foundation acts not only as a coarse filter, through which the water is rapidly drained away, but it also forms a very solid foundation upon which certain kinds of pavement, especially granite block and brick, may be laid with safety. In places where the subsoil is sand and gravel and the traffic is comparatively light, the construction of a concrete foundation for brick or stone block pavements is an unnecessary expense. I have in mind a brick pavement laid on a sand subsoil which has been in use for nearly ten years, which pavement shows absolutely no deterioration as a result of the sand foundation. This pavement does not even have the joints filled with cement grouting. It might have been well to have filled the joints with cement because these openings are places for the possible accumulation of refuse. As it is, the sand foundation offers exceptionally favorable conditions for the rapid removal of the ground water.

In case the subsoil is clay or muck, the introduction of sand and gravel, as a foundation, will prove serviceable, provided a sufficient thickness is used. Five or six inches is not enough, unless the traffic is very light. Usually it requires the addition of twice that amount. A subsoil, which requires by nature the addition of such a thickness of sand and gravel, might better be covered with a more permanent foundation, such as concrete.

For the ordinary subsoil, a mixture of ten per cent sand, ten per cent clay and eighty per cent gravel in pieces of all sizes up to two inches in diameter is considered most desirable. An excellent foundation is made out of five inches of stream gravel and three inches of clean sharp sand thoroughly rolled. Gravel and sand used as a foundation should in no case contain more than fifteen to twenty per cent of clay.

Wooden Foundations—Wooden foundations have been used almost exclusively in the construction of wooden block pavements. These usually consist of two-inch plank laid on 2x4 inch stringers



Diagrams illustrating one of the best types of a vitrified brick pavement. Note the gutter construction which is intended to keep the water away from the curb. Instead of eight, it would be better to lay twenty to thirty courses of brick lengthwise of the street next to the curb.

embedded in sand or gravel. In case two thicknesses of plank are used, they should be laid at right angles to each other, either lengthwise or crosswise of the street. In case one thickness is used, they should be laid crosswise of the street or diagonally. Wooden foundations have proven unsatisfactory, on account of their cost and the unsanitary conditions which they develop within a few years. Eventually, both the wooden blocks and the plank foundation become saturated with water, causing mildew and decay. As the planks rot the blocks settle, and the surface of the pavement becomes uneven and billowy. At most, the plank foundation has been only a temporary expedient.

Broken Stone—As a foundation for pavements, there is probably no material more generally used than broken stone. Where macadam and telford pavements are built, broken stone is used almost exclusively for the foundation. On a street where it has become necessary to replace a macadam pavement with that of a more durable character, the macadam is frequently brought to the proper grade for the foundation to the new pavement by the addition of more broken stone, after which it is thoroughly compacted by rolling. Upon such a foundation a brick, stone block or asphalt superstructure may be laid.

A broken stone foundation differs from concrete in that cement is used to bind the fragments of the latter, while finely powdered stone serves this purpose in the former. A thickness of six or eight inches of broken stone is usually sufficient to serve as a foundation for pavements on all streets, except those that are subject to heavy traffic or those that are located in places where the subsoil is unusually soft during any season of the year. As a rule, a broken stone foundation is less expensive than concrete, and in many places it serves equally well. The difference in the cost of the two foundations is sufficient, in many instances, to pay for building an increased amount of pavement.

In case broken stone is used as a foundation for block or sheet pavements, care should be exercised to make the surface impervious. In constructing the foundation, the voids between the larger pieces should be well filled with screenings and thoroughly tamped, so that none of the pieces can move about, and thus destroy their angularity.

Broken brick, slag, cinders and burnt clay ballast may be used in place of broken stone, in which case the same precautions as to the method of construction should be observed.

Brick—It is the practice in some localities, in the construc-

tion of brick pavements, to lay two courses of brick, one of which serves as the foundation and the other as the superstructure. In case brick is used as a foundation, the joints should be filled with cement in order to render it impervious. In some cities the brick in worn-out pavements are turned and relaid as the foundation for asphalt or another brick pavement. In this position they have served well, and have naturally reduced the cost of constructing the pavement. The use of brick as a foundation is only practiced in localities where the cost of construction is materially lessened thereby.

Stone Blocks—Granite and limestone blocks, such as are used for surfacing, are too expensive for foundations. Occasionally, however, stone blocks which are partly worn out are taken up, turned and relaid, usually on their side, to serve as a foundation for a superstructure of asphalt or some other of the common pavements.

Other than this, stone blocks are used for foundations only as a part of telford pavements. Blocks used for this kind of pavement are usually of irregular size and shape, and are spoken of as rubble stone.

Concrete—This is the most universally accepted material for the foundation to asphalt, brick and stone block pavements. Concrete is a mixture of gravel or crushed stone, sand and cement. When properly constructed, a concrete foundation resembles in hardness and appearance a sheet of conglomerate. Under ordinary subsoil conditions, a thickness of five or six inches is sufficient to sustain the traffic on most streets. The thickness, however, should be greater or less, depending upon the nature of the traffic and the character of the subsoil.

In the manufacture of concrete, broken limestone, granite, greenstone, quartzite or any other solid rock may be used. In some instances broken vitrified brick, slag, burnt clay ballast and gravel have been substituted for broken stone. In case the brick are thoroughly vitrified they are preferable to limestone, although granite, quartzite and greenstone or trap rock are most desirable. Eighty-five per cent of the stone should consist of pieces between one and a half and two and a half inches in their greatest diameter. The remaining fifteen per cent should consist of finer grades not larger than the greatest diameter of the interspaces between the coarse stone. In all cases the stone should be free from dust and dirt.

The sand used should be coarse, sharp and clean, preferably

quartz. However, in the place of quartz, limestone, granite or quartzite screenings may be substituted.

Portland cement is preferred in the construction of concrete foundations, although it has been fairly well demonstrated that natural cement will withstand the agents of disintegration, which are active in the destruction of the foundations to pavements. In concrete constructions it is thought best not to specify any particular brand of cement. This should be left to the engineer, who should be governed in his choice by the results of certain standard tests, as indicated in the contract. Specifications for cement should require that it be new and finely ground. At least 85 per cent should pass through a sieve having 10,000 meshes to the square inch. It should have a tensile strength of 500 pounds per square inch when mixed pure and made into briquettes which have been exposed to the air for 24 hours and immersed in water six days. Cement which meets these requirements ought to be suitable for use in concrete foundations. A further check on the strength of the cement may be had by requiring tests of briquettes made out of one part by weight of cement and three parts by weight of clean, sharp sand, which will pass through a sieve having twenty meshes per lineal inch and be retained by one having 30 meshes per lineal inch. These briquettes should have a tensile strength of 250 pounds per square inch after being exposed to the air twenty-four hours and immersed in water six days. The street commissioner or engineer in charge of the construction should be required to test *all cement*, and he should be given authority to reject any which is exposed to the weather after being tested. He should also have the privilege of re-testing any cement which he may have reason to believe has not been properly cared for after having been once tested.

The concrete should be made out of seven parts of broken stone and five parts of cement mortar. The cement mortar should consist of one part by volume of cement and four parts of sand. The cement and sand should be mixed while dry until perfectly homogeneous. This mortar should be prepared in a tight box, the water being added after the cement and sand are thoroughly mixed. In case it shows evidence of beginning to set before being mixed with the broken stone, it should be rejected. The cement mortar and stone should be mixed immediately after the mortar is made. This is accomplished by pouring the mortar into the stone and turning it with shovels and rakes on a tight platform constructed for that purpose. When once made, the concrete should be immediately

placed upon the subgrade to the required thickness and compacted to a smooth surface conforming to the grade and cross section of the street. It should be thoroughly compacted with iron rammers until the surface is smooth. This should be covered with half an inch of cement grouting, consisting of one part of cement and four parts of sand.

Where the expense will admit, mechanical concrete mixers are recommended. The devices now employed for mixing the sand, cement and broken stone produce more uniform results than mixing on a platform with shovels.

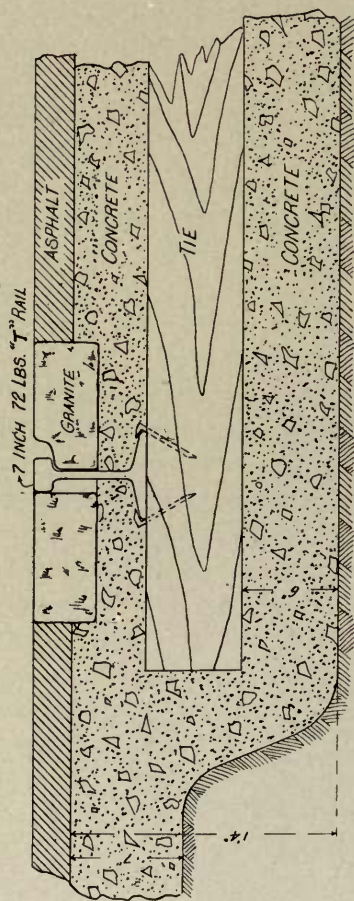
During the period it is required for the cement to set no traffic should be allowed to pass over the foundation, and street cars should not be allowed to use the thoroughfare. All the care used in the construction of the foundation may be valueless, if this precaution is not observed. It requires at least twenty-four hours for the cement to harden sufficiently to permit of traffic. The success of a concrete foundation depends chiefly upon the use of proper cement; the care which is exercised in its preparation; and the removal of traffic of any kind until the cement has set. When properly constructed, there is no foundation better than concrete.

Miscellaneous Materials—Among the miscellaneous materials used for foundations are furnace slag, cinders and broken brick. These have been referred to on the preceding pages. They are used in essentially the same manner as broken stone, being especially well adapted for the foundations to cement curbs, gutters and granolithic walks. The inexpensive character of these materials renders their use eminently desirable in some localities.

In some sections of this State there is an abundance of broken stone known as chat. On account of the fineness of this material it is not as desirable as broken stone, owing to the fact that it requires the use of a greater percentage of cement. However, the cheapness with which this material may be obtained sometimes compensates for the cost of additional cement. In such cases there is no objection to the use of this material.

Resume—For heavy or light traffic streets, upon which wooden block, asphalt, brick or stone block pavements are to be constructed, either concrete or well compacted macadam foundations should be used. The foundation for pavements on heavy traffic streets should be limited to concrete if the best results are desired. On residential streets, and in exceptional cases of light traffic streets, sand and gravel or macadam may be used with en-





ONE METHOD OF CONSTRUCTING AN ASPHALT PAVEMENT AND GUTTER, SHOWING STREET CAR TRACK.

tire satisfaction. This, however, will depend also upon the character of the subsoil. In some instances it may be desirable to use a concrete foundation, even though the traffic be very light.

THE CUSHION.

In order to give elasticity to brick or block pavement, it is customary to cover the foundation with a layer of from $1\frac{1}{2}$ to 2 inches of clean, sharp sand. In the construction of other pavements this cushion of sand is not used. In the case of sheet asphalt pavements, the binder course of $1\frac{1}{2}$ inches takes the place of the cushion. It consists of bituminous concrete, and is composed of clean broken stone, slag or gravel, not over $1\frac{1}{2}$ inches in the largest dimension, and asphaltic cement. The asphaltic cement is mixed with broken stone or gravel in the proportion of about 15 gallons of cement to one cubic yard of stone.

In the case of block pavements, where the joints are filled with a grouting of asphalt or Portland cement, the cushion is in part, at least, saturated with the mortar poured into the joints.

THE SUPERSTRUCTURE OR SURFACE.

The modern street pavement, as a rule, has a surface of either sheet asphalt, rock asphalt, asphalt block, vitrified brick, stone block, broken stone, wooden block, tar macadam, slag, slag block, cement concrete or glass block. Other materials used for surfacing are cobble stone, gravel, cinders, planks, logs, clay, charcoal, burnt clay and rubber.

Asphalt—Before this pavement is laid, granite blocks should be laid on both sides of each rail of the street car tracks, around all valve boxes, manholes and other openings, and at each intersection, as a protection to curbs. The blocks along the street car tracks should be laid as stretchers and headers. The surface of these blocks should be on a level with the surface of the finished pavement. They should have smooth heads and close joints, not exceeding $\frac{3}{8}$ of an inch in width. The upper surface of the blocks should be at least 8 inches and not more than 13 inches long, from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches wide and from 4 to 5 inches in depth. Blocks which are not uniform in texture and composition and are of irregular shape should be rejected. All granite blocks used in these places should be laid with the concrete foundation and should be embedded in a cement mortar. The joints should be filled with an asphaltic paving cement, composed of 20 parts of refined asphalt and 3 parts of residual oil, mixed with 100 parts of coal tar. The

coal tar, oil and asphalt should be mixed at the place where it is needed for immediate use. It should be poured into the joints at a temperature of 300° Fahr. After filling the joints with this cement, dry hot gravel should be poured into them, and the same lightly tamped with a rammer.

After the granite blocks have been set, the binder course of bituminous concrete should be added upon the concrete or macadam foundation. This concrete should consist of finely crushed limestone, granite or quartzite and asphaltic cement as described above. The broken stone should be heated by passing through revolving heaters and thoroughly mixed with the asphaltic cement in the proportion of about 15 gallons of cement to one cubic yard of crushed stone. This binder should be spread, while hot, on the foundation with iron rakes. It should be immediately rammed and rolled until it has a uniform thickness of 1½ inches. The upper surface of the binder course should be made parallel with the grade and profile of the finished pavement. Should any portion of the binder not show a proper bond, it should be immediately removed and replaced.

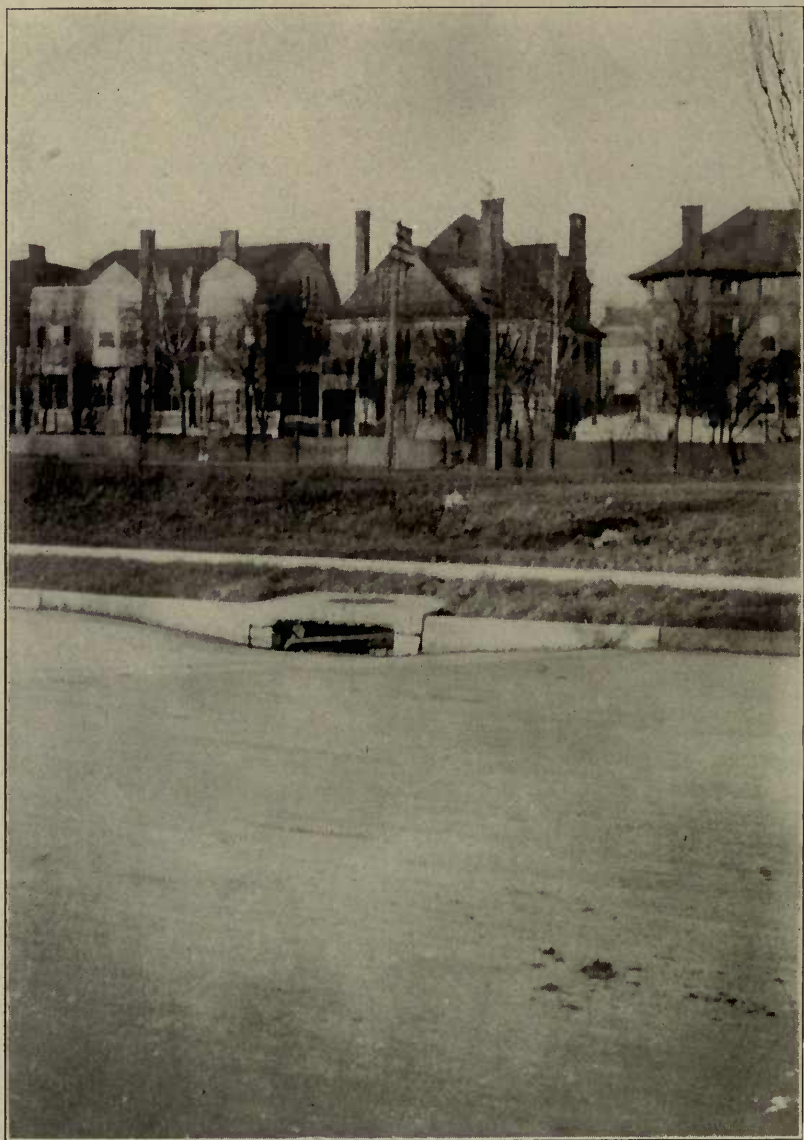
Upon the binder course, there should be spread a wearing surface 1½ inches in thickness. This should consist of 17 parts of asphaltic cement, 73 parts of sand and 10 parts of pulverized granite or quartzite. The asphaltic cement should be the same as that described above. The sand should be clean, coarse and sharp. Most specifications call for carbonate of lime instead of quartzite or granite, but it is thought that the use of limestone is one of the causes for the rapid deterioration of the pavement.

The sand and asphaltic cement should be heated separately and mixed at a temperature of about 300° Fahr. The granite or quartzite are usually mixed while cold with the hot sand. These in turn being thoroughly mixed with asphaltic cement at the temperature indicated above.

This paving mixture should be spread upon the binder course in one coat and at a temperature of not less than 250° Fahr. The surface should be compressed with rollers, and afterwards swept with a small amount of hydraulic cement. Finally it should be compressed with a 15-ton roller, worked crosswise and lengthwise of the pavement. Rolling should be continued until no impression is made upon the surface.

The grade of the finished street should, everywhere, be ⅓ to ¼ of an inch higher than the granite blocks laid along the street car tracks and around manholes, catch basins, etc.





ASPHALT PAVEMENT AND SEWER INTAKE, McPHERSON AVENUE,
ST. LOUIS, MO.

In case brick or granite blocks are used for gutters, they should be laid at the same time that those along the tracks and around the manholes are laid.

Additional discussions and illustrations covering the method of constructing asphalt pavements may be found in the numerous specifications issued by the larger cities of this country.

Asphalt blocks—The manufacture of asphalt blocks was commenced in 1869, but not until the introduction of powerful mechanical presses in 1880 was it possible to manufacture a block which had the required strength and durability. For a number of years limestone was used in the asphaltic mixture, but this stone proved too soft, and trap rock and granite have been substituted.

Asphalt blocks are manufactured out of an asphaltic cement composed of refined asphalt and petroleum oil, which are mixed mechanically with crushed rock, at a temperature of 300° Fahr. This mixture is moulded into blocks and subjected to a pressure of 120 tons. The common type of asphalt block measures 12x4x3 inches and weighs 13½ pounds. Blocks of other sizes and shapes are manufactured.

It is claimed for these blocks that they are not slippery and that pavements constructed out of them are quiet. The blocks are non-absorbent, which renders them in a high degree sanitary. They may be laid on any of the above described foundations, although concrete is the surest and most serviceable. In case a concrete foundation is used, the blocks are laid directly on the mortar surface. When old stone block, macadam or gravel pavements are used as foundations, they are covered with a cushion of 1½ inches of sand.

Natural Rock Asphalt—Rock asphalt consists of porous limestone or sandstone, the interstices of which are filled with bituminous matter, which is sometimes, but not always, asphalt. The asphalt rock obtained from different localities varies quite widely. On this account, cities using this material usually specify the locality from which the asphalt must be obtained. The St. Louis authorities have specified that natural asphalt rock pavements must be made from bituminous sandstone from Kentucky or Indian Territory. In most cases where bituminous sandstone is used, the contractor is permitted to mix either 10 per cent of pure carbonate of lime or an equal portion of bituminous limestone. The mixture which is used for paving should contain about 80 per cent

of silica, not less than 10 per cent of bitumen and not more than 10 per cent of carbonate of lime.

Bituminous limestone and sandstone when used for paving should be finely ground and thoroughly mixed without the addition of any extraneous materials. This mixture should be placed in a steam heating machine and heated to a temperature of not less than 250° Fahr. The mixture should be spread on the street at a temperature of not less than 250° Fahr. and to such a depth that after it has been thoroughly compressed it will have a thickness of 2 inches. After being spread, it should be raked smooth, rolled with a 2-ton steam roller and covered with a thin layer of hydraulic cement. The surface should finally be compressed with a steam roller of not less than 5 tons weight. The pavement should be rolled until the roller makes no impression upon the pavement itself.

The great difference in the composition of asphaltic sandstones and limestones from different localities makes it somewhat doubtful as to whether this material can ever take the place of the usual sheet asphalt pavement. Specifications for natural rock asphalt call for not less than 10 per cent of bitumen, without reference to the quality. The nature of the bitumen undoubtedly influences very considerably the durability of the pavement, and it is thought that some standard should be adopted to govern the quality of the bitumen present in the rock. The presence of more than 10 per cent calcium carbonate is said to be deleterious to the pavement. Some of the asphalt rock now quarried is limestone, and for this reason it is well to observe that when used alone such material will have a tendency to cause the pavement to disintegrate rapidly.

It is doubtful if this material will ever be used very extensively for the construction of permanent pavements where the cost nearly equals that of the ordinary asphalt pavement. Only in localities in close proximity to deposits of rock asphalt can this type of pavement be economically constructed. There are quite extensive deposits of both asphaltic limestone and asphaltic sandstone in some portions of this State, and it is thought that for use in the territory immediately adjacent to these deposits they might be advantageously exploited.

Brick—One of the most important materials for paving in cities is vitrified brick. The brick pavement is suitable for light business traffic and some heavy traffic streets. Vitrified brick are manufactured in two sizes, 2 or 2½"x4"x8" and 8" to 9¼"x4"x3½" to



1. Asphalt pavement with cement combined curb and gutter, St. Louis, Mo.
2. Junction of brick and asphalt pavements, St. Louis, Mo.

3 $\frac{3}{8}$ ". The former is known as vitrified paving brick and the latter as vitrified paving blocks. In case the brick and block sizes are equally well vitrified the choice of one or the other is chiefly a matter of taste. There is, perhaps, a greater probability of securing a uniform and thoroughly vitrified product by specifying the brick rather than the block size. In the burning of vitrified brick there is always danger of raising the heat a little too high or not quite high enough, on account of which under and over-burned brick are produced. In the rush of business it also frequently happens that a kiln of brick is cooled too rapidly, on account of which the annealing is checked. As a result of these conditions, paving brick should be sorted into three grades. The first grade should include all those that are thoroughly vitrified and perfect in shape. The second grade should include soft or under-burned brick. The third grade should include brick which have been warped or checked as a result of over-burning. Some manufacturers grade their brick, others do not. The basis upon which brick are graded is not the same at all factories, and for this reason one should be thoroughly acquainted with the different grades of brick from the different factories that are under consideration. Every car load of brick received should be sampled and tested before being accepted, all over-burned and under-burned brick being scrupulously rejected.

When removed to the street, the brick should be carefully piled on the sidewalk next to the curbing. Before laying, the sand cushion should be compacted and carefully spread until the surface is exactly parallel to the grade of the finished pavement. This is accomplished by using a wooden screed, one side of which is cut to the proper curve. No sand should be added to the cushion by hand, and the surface of the cushion should be in no way disturbed during the laying of the brick.

The brick should be laid on edge, end to end, and in parallel courses at right angles to the line of the street, except at street intersections, where the courses may be laid diagonally or at such other angle as may be thought proper. The joints should be broken near the middle of the brick, and the brick should be laid so that the sides and ends touch. They should be set sufficiently high, so that after pounding and rolling the surface will conform to the desired grade. No broken brick should be used except in starting or finishing a course at the curb, catch basin, rail or other structure where it is necessary to break joints. Wherever half bricks are used, they should be carefully cut and fitted, care being

exercised not to injure the brick by trimming or breaking to the proper size. Some factories now manufacture brick of half size, obviating the necessity of breaking whole bricks. In all cases experienced men with proper tools should be employed for the construction of a brick pavement.

In case a brick pavement is to be laid up to the curb, some advantage is gained by laying 10 or 15 courses of brick lengthwise next to the curb to serve as a gutter. In some instances the brick next to the gutter are gradually raised in order to carry the water away from the curbing, thereby protecting it.

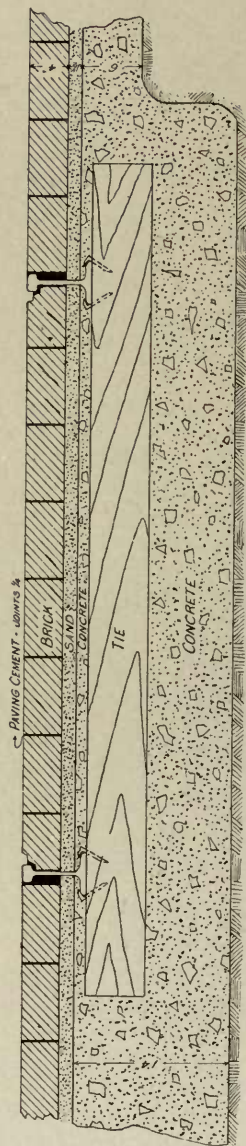
An expansion joint should be provided on each side of the pavement, and at right angles with the street, at intervals of 50 feet. This joint should be filled with pitch, heated to a temperature of about 300° Fahr. Such joints should be filled to within 1½ inches of the surface.

The joints should be filled either with a coal tar paving cement or Portland cement grouting. The coal tar cement is obtained by direct distillation of coal tar at a temperature of not less than 400° Fahr. It should be used while hot and only when the bricks are thoroughly dry. All joints at the gutters, curbs, rails, catch basins, etc., should be completely filled, but care should be exercised not to pour cement over the surface. The highest grade of Portland cement should be used in the preparation of cement grouting. This grouting should consist of equal parts of Portland cement and sand, thoroughly mixed and dried in portable boxes, sufficient water being added to make a cement of proper consistency. A water bucket of this cement should be made at a time and immediately transferred to the pavement in scoop shovels and swept rapidly into the joints with steel brooms. The grout in the box should be constantly stirred in order to prevent the sand and cement from separating. After the pavement has been grouted, traffic should be kept off of the street for a period of ten days. Unless these precautions are observed, the cement grouting will not prove satisfactory. After the pavement is finished, it should be covered with ½ inch of clean, coarse sand, to be removed later at the discretion of the street commissioner or city engineer.

In some instances the joints are filled with sand instead of cement. In such cases the joints serve as places for the accumulation of filth and refuse, and also act as channels through which the water is drained.

In case it is not expected to fill the joints with Portland cement





A BRICK PAVEMENT SHOWING MANNER OF CONSTRUCTION WHERE RAILWAY TRACKS OCCUR.
Note that the T rail is used, and that the ties are embedded in concrete.

grouting, brick with round edges and corners are preferable to those which are square. Square-cornered brick are more liable to be chipped and broken than those with round corners, except where the joints are filled with cement grouting. A pavement in which round cornered brick are used is rougher than a cement-grouted square-cornered brick pavement, but furnishes a better foothold for horses. The choice of brick depends chiefly upon the grade of the street upon which the pavement is to be laid, a smooth pavement being most desirable for a level street.

The following is a copy of the directions for laying the best known type of brick street pavement, recommended by the National Paving Brick Manufacturers' Association. Accompanying the instructions, reasons for them are given.

"DIRECTIONS FOR LAYING BRICK STREET PAVEMENTS."

SUBSTRUCTURE OR GRADING.

Earth in excavation to be removed with plow and scraper, or other device, to within two (2) inches of subgrade, then brought to the true grade with the roller, the weight of which should not be less than five (5) nor more than eight (8) tons. If the earth is too hard to receive compression through the roller, then loosen the remaining inches with a pick and cart away.

Earth in embankment must be applied in layers of eight (8) inches in thickness, and each layer thoroughly rolled, and in both excavation and embankment the subgrade must have a uniform density.

If the underground is spouty clay, tile drainage should be provided to carry off this accumulation of wet.

REASONS WHY.

The attempt to remove earth to the proper depth or grade line with plow and scraper is usually fatal to the general surface of the subgrade, for the reason that no man can hold a plow, or team draw the same to a straight grade; therefore, in an attempt to get too close to subgrade with a plow, holes will be gouged below the true grade. When the shovelers commence the removal of the plowed earth, they will invariably sink these same low places still lower, and when the finishing begins these low places will necessarily have to be filled and compacted with the roller. Then you have different characters of solidity, which are objectionable and detrimental to good work.

The prime reason for not using a roller weighing more than eight (8) tons is that they are too cumbersome and unwieldy, and very slow moving, while with a lighter and quicker moving one you pass many times over the subgrade and get better results in having your subgrade more uniformly compacted.

The filling with loose earth of portions of the work that is below grade will be found necessary very often if an attempt is made to plow too close to the grade line; then the lighter roller is found more effective in bringing such places to the same density as the undisturbed portion.

When the embankment is necessary to bring the street to the required grade line, it is very obvious that the earth should be deposited in equal layers of not more than eight (8) inches thick, and each layer thoroughly rolled. A six or eight ton, or even a heavier roller, will have little effect in compression below eight inches, and all embankments should be compacted as thoroughly as possible before applying the superstructure; for earth once disturbed and removed from its natural

bed takes a long time to acquire its original solidity, the scientific reason for which would take too much space and time to enter upon here.

Underdrainage is not absolutely essential, but in wet and spouty under stratum much is added to the durability of the structure by keeping the sub-foundation dry, and under foregoing wet conditions under-drainage is the only way to accomplish the best results.

CURBING.

Stone curbing should all be hauled and distributed and set before the grading is finished, and may then be used as a guide to finish the subgrade.

It should range in thickness from four (4) to six (6) inches, twenty (20) to thirty-six (36) inches wide, the business and street traffic governing the same, and lengths not shorter than four (4) feet, except at closures; neatly dressed on top with a square or rounded edge, and four (4) inches down on the inside. The outer surface to be tool-dressed to the depth of the face exposed and to the depth of the thickness of the brick and sand cushion. If cement concrete curb is used, it should be completed before the work of finishing the subgrade begins.

Curb corners of streets and alleys should be made circular.

EXTRA MENTION.

If concrete curb and gutter is used, it must be placed in position before any of the other work is commenced, except, possibly, some of the heavier grading, and it is essential, if natural stone curb is used, to have it all in place before any portion of the grading is finished, for the reason that, after you have finished a subgrade and given it the proper contour and surface, it should never be disturbed by unnecessary wheelage, and nothing destroys it so effectually as hauling heavy stone curb over it; and in renewing these broken places they are rarely returned to the original conditions.

The curb should all be set before the finishing of the subgrade begins, if for no other reason than that it affords the very best guide for the said finishing.

MARGINAL CURB.

Should always be of a hard and durable character of stone, and from fourteen (14) to eighteen (18) inches deep, dressed on top, and five (5) inches down on the face next to the brick. Set to accurately fit the curvature of the cross section of the street on six (6) inches of concrete and backed up with the same within six (6) inches of the top.

EXTRA MENTION.

Marginal curb should always be of a hard and durable character of stone (hard wood is better than soft stone), and set on and backed up with a good Portland cement concrete, mixed in the proportion of one to two to four.

Marginal curb is, as a rule, used to sustain a paved street against one that is unpaved; therefore, the reason it should be well and properly set, and, unless it is, the impact of the wheelage in passing from the unpaved to the paved street will soon drive it down and loosen it, if not firmly and securely set, and in a short time the pavement begins to break and give way, and will continue to do so for quite a distance into the intersection.

Even with the marginal curb set in the above manner, there should be a margin of crushed stone or clean gravel to the width of three or four feet and eight (8) or ten (10) inches deep spanning the width of the opposing unpaved street and tamped firmly against the marginal curb. With these precautions you will avoid the rapid destruction of the margin of your paved streets.

CONCRETE FOUNDATION.

Should be of approved quality of hard rock, free from all refuse and foreign matter, with no fragment larger than will pass through a two (2) inch ring, and no smaller than will pass through a one (1) inch ring in their longest dimensions.

Clean, sharp, dry sand, thoroughly mixed in its dry state, with an approved





BRICK AND MACADAM PAVEMENTS, RICHMOND, MO.

brand of either hydraulic or Portland cement until the whole mass shows an even shade. If hydraulic, the proportion of mixture should be one part of cement and two parts of sand. If of Portland, one part of cement to three parts of sand.

To the above mixture should be added sufficient clean water to mix to a plastic mass, fluid enough to rapidly subside when attempted to heap into a cone shape. To this mixture add four (4) and six (6) parts, respectively, of damp crushed stone, or good gravel carrying sufficient sand to make the mixture, and then turn the whole mass over not less than three (3) times, or until every fragment is thoroughly coated with the cement mixture. For the reception of this mixture, the grade should be set off in five-foot squares, with a stake at each corner. Tops of each should be at the surface of concrete, which must be tamped until free mortar appears at the surface. Occasional sprinkling in extra hot, dry weather is beneficial. After thirty-six hours the cushion sand may be spread.

EXTRA MENTION.

If the combination of gravel and sand is used, the mixture for natural cement should be one (1) measure of cement to six (6) measures of the mixture. If Portland cement, one (1) measure of cement to eight (8) measures of the mixture.

There is but one way to make good cement mixtures, presuming, of course, you have good material, and that is to thoroughly mix the dry materials. It is essential that the sand and cement should be thoroughly incorporated in this dry state; if not, then it can't be done after the water is applied. In the first, you will have a homogeneous mass; in the second, a heterogeneous. In the one your mixture is complete and your structure is uniform; in the other, it varies, and your structure is uncertain. The above applies especially to platform mixing. On machine manipulation the dry mixing isn't so readily obtainable, but could be more nearly approached if greater care were taken. Thorough mixing in both dry and wet state, with good material and proper proportions, insure a good concrete, whether it be of crushed stone or gravel.

SAND CUSHION.

Sand should be clean and free from foreign or loamy matter. It need not necessarily be sharp. It should be two (2) inches thick before the compression of the brick by rolling. The sand should be spread by the aid of a template the whole or one-half the width of the street, and made to conform with the true curvature of the street cross section.

EXTRA MENTION.

The preparation of the subgrade having been, with care, brought to a true plane as to curvature and grade, and to a uniform thickness, the work is ready for the cushion for the brick, for which any good clean sand may be used, whether it be sharp or spherical, but it is next to the impossible to spread it satisfactorily with a template or in any other manner when it is wet, and if you insist on your pavement maintaining its symmetrical form the sand must be evenly spread; and there is but one method for doing this, and that is mechanically, by the aid of a template, formed to fit the curvature of the street and armed with small metal wheels at either end, rolling on the curb at one end and on a 4"x4" scantling laid lengthwise through the center of the street at the other.

If the roadway of the street isn't to exceed twenty-five (25) feet in width or less, the template can be made to span the entire width, both ends rolling on the curb.

This manner insures an even thickness of sand over the surface of the concrete, giving to each individual brick a like thickness of cushion, so that when the brick surface is rolled each brick will present the same resistance to the pressure of the roller, and you will then perforce have a smooth surface, otherwise if the sand is of uneven thickness the tendency of those brick resting over the thicker bed of sand is to sink, under the pressure of the roller, lower than those resting over a thinner layer, and the result is an undulating and uneven surface.

BRICK.

The brick should all be hauled and neatly piled within the curb line before the grading is finished, or, if allowed by the engineer, delivered in wagons and carried from the pile or wagon on pallets with clamps—not wheeled with barrows. In hauling from car no throwing or dumping is allowed. They should be first class and thoroughly vitrified, showing at least one fairly straight face; if the edges are rounded the radius should not be greater than $\frac{3}{16}$ of an inch. They should not be less than $2\frac{1}{4} \times 4 \times 8$, or more than $3\frac{1}{2} \times 4 \times 9\frac{1}{2}$ inches, free from cracks, with but slight lamination, and at least one edge with but slight kiln marks allowed, and should stand the tests promulgated by the National Brick Makers' Association.

EXTRA MENTION.

It is not only good practice to have all of the brick hauled and distributed just inside the curb line before the work of grading begins on any street block, but it is economy, as experience has taught us that it is very expensive to attempt to get brick into a block after the other work has begun. Each side of the street should have the required number of brick neatly ricked up to lay to the center of the street, thereby always maintaining the minimum distance to carry the brick to the setter.

In order to get the brick to the setter with the least possible abrasion or injury to the same, it is best to carry them on pallets, and so deposit them that the person laying them in the street will deposit them face edge up. No wheeling or teaming should be permitted over the brick at any stage prior to opening the same to the public.

BRICK LAYING.

Brick may be laid either at a right angle or at an angle of 45 degrees to the curb as the Engineer may direct, and in either way the line or course of brick must be kept straight or within a maximum variation of two inches; if greater than that, as many courses as necessary should be taken up and relaid until the defect in alignment is removed.

No parts of brick should be allowed in the pavement except the beginning or ending of courses or other closures. The brick must be laid with the best edges exposed as near in contact as possible; they must be closely inspected before laying and also after laying and after rolling. And all soft brick, or badly spalled or ill-shapen, must be removed and replaced with perfect ones. The kiln marked ones may be turned over, and if the reverse edge is smooth and no other faults be found, it can remain in the pavement.

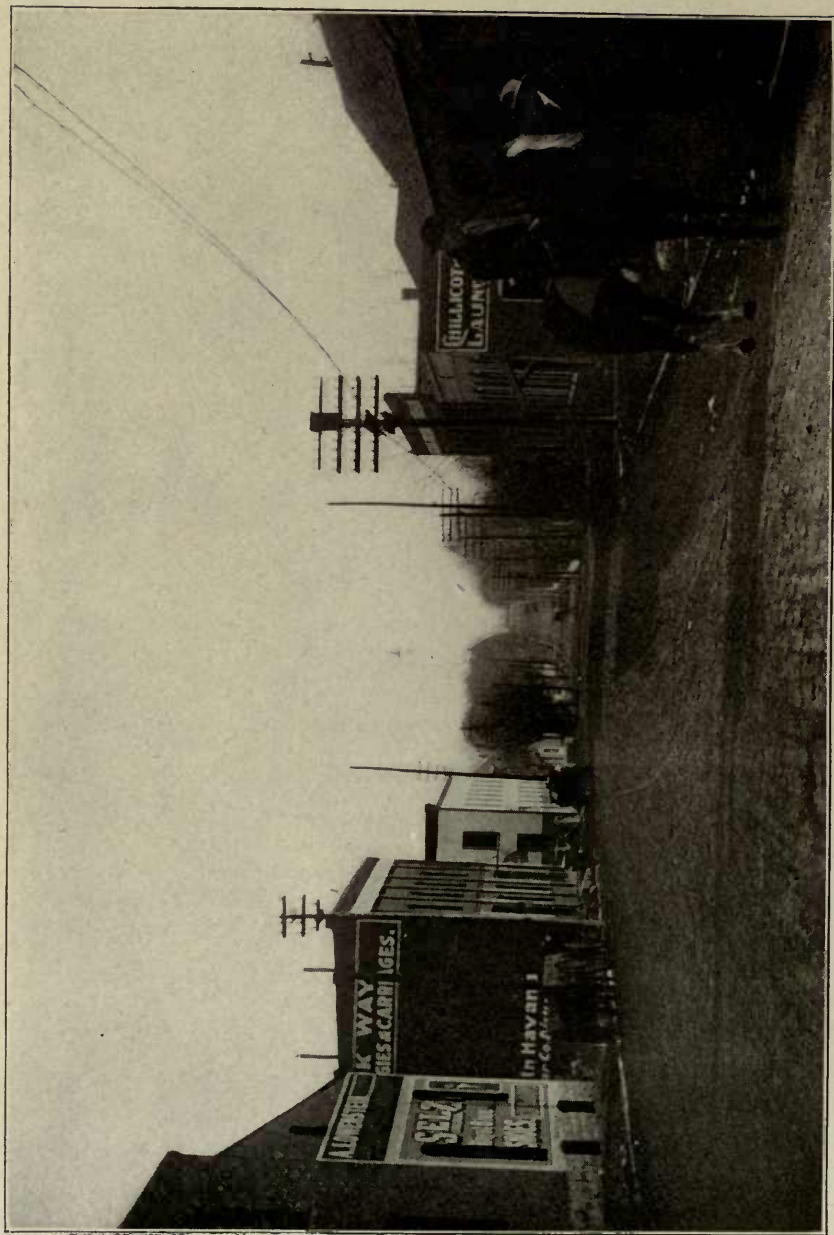
EXTRA MENTION.

As to the alignment of the courses of the brick, there is but little choice; either way is admissible without comment. The brick should be as nearly in contact as it is possible to lay them, for when the rolling is in progress, if there is appreciable space between the brick in the compression and bedding into the cushion sand, the brick will have a tendency to rock, and instead of receiving a flat foundation, as they should, it will be in a curved form, made by the rocking of the brick as the roller passes on and off them, and the pavement will require more grout to fill the interstices.

It is not bad practice, if the gutter gradient is very flat, to lay five or six longitudinal courses parallel with the curb, as there will be less hindrance to the gutter drainage.

ROLLING AND TAMPING.

After the brick in the pavement are inspected and the surface is swept clean of spalls, they must be well rolled with a five (5) ton steam roller in the following manner: The brick next the curb should be tamped with a hand wood tamper to the proper gutter grade. The rolling will then commence near the curb at a very slow pace and continue back and forth until the center of the pavement is reached,



VIEW OF PAVEMENT ON CALHOUN STREET, CHILICOTHE, MO.

then pass to the opposite curb and repeat in the same manner to the center of the street. After this first passage of the roller the pace may be quickened and the rolling continued until each brick is firmly imbedded in the sand cushion. The roller shall then be started at the end of the block and the pavement rolled transversely at an angle of 45 degrees to curb; repeat the rolling in like manner in the opposite direction. Before this transverse rolling takes place all broken or injured brick must be taken up and replaced with perfect ones.

EXTRA MENTION.

There is no question open to discussion as to the virtue of a steam roller on a brick pavement. It is very necessary in order to give it a smooth surface. The transverse rolling is very necessary in order to remove the slight wavy condition of the surface, extending laterally from curb to curb, which will occur after the longitudinal rolling, and is the result of the thrust or impact occasioned by the propelling power of the roller. If the roller was drawn instead of being propelled, these apparent waves would not occur. Therefore, the transverse rolling will practically remove them. The longitudinal rolling should always be from curb toward the center. The curved transverse section of the street has a tendency to move the brick endwise toward the curb; therefore, under the pressure of the roller, if you start the roller in the middle and roll toward the curb the gutter bricks that you have previously tamped to grade will be very much disturbed and your flow line will require retamping. If it were practicable to use the roller absolutely against the curb, the rolling might be done from the center to the curb.

EXPANSION CUSHION.

An expansion cushion must be provided for, one inch in thickness next to the curb, filled two-thirds of its depth with pitch, the top one-third being filled with sand.

EXTRA MENTION.

This pitch joint next to and along the curb answers two purposes; it takes up the expansion of the brick and prevents a possible cracking of the pavement. through and along the center of the street, which sometimes occurs if the ends of the course of the brick are abutted directly against the curb which acts as a skewback or haunch to the arc of the pavement, which is often strong enough (especially if the sidewalk is up to and against the inside of the curb) to resist the force of expansion in that direction, and it will find relief in raising the pavement and the cracking mentioned above may occur. And, again, in taking up the expansion the brick are kept in contact with the sand cushion below, thereby preventing the rumbling noise so often heard, and occasioned wholly through lack of contact.

The inch of sand on the top of the pitch joint has a tendency to prevent the pitch from flowing, which it is likely to do in very hot weather. It is essential that the board occupying the place to be filled with pitch remain in place until after the street is in all other respects finished, but always withdrawn and the pitch applied within 36 hours after the application of the cement filler.

THE FILLER.

The filler should be composed of one part each of clean sand and Portland cement. The sand should be dry. The mixture, not exceeding one-third bushel of the sand, together with a like amount of cement, shall be placed in the box and mixed dry, until the mass assumes an even and unbroken shade. Then water shall be added, forming a liquid mixture of the consistency of thin cream.

From the time the water is applied until the last drop is removed and floated into the joints of the brick pavement, the same must be kept in constant motion.

The mixture shall be removed from the box to the street surface with a scoop shovel, all the while being stirred in the box as the same is being thus emptied. The box for this purpose shall be $3\frac{1}{2}$ to 4 feet long, 27 to 30 inches wide and 14 inches deep, resting on legs of different lengths, so that the mixtures will readily flow to the lower corner of the box, which should be from 8 to 10 inches above the

pavement. This mixture, from the moment it touches the brick, shall be thoroughly swept into the joints.

Two such boxes shall be provided in case the street is twenty feet or less in width; exceeding twenty feet in width, three boxes should be used.

The work of filling should thus be carried forward in line until an advance of fifteen to twenty yards has been made, when the same force and appliances shall be turned back and cover the same space in like manner, except to make the proportions two-thirds Portland cement and one-third sand.

To avoid the possibility of the thickening at any point, there should be a man with a sprinkling can, the head perforated with small holes, sprinkling gently the surface ahead of the sweepers.

Within one-half to three-quarters of an hour after this last coat is applied and the grout between the joints has fully subsided and the initial set is taking place, the whole surface must be slightly sprinkled and all surplus mixture left on the tops of the bricks swept into the joints, bringing them up flush and full.

After the joints are thus filled flush with the top of the bricks and sufficient time for evaporation has taken place, so that the coating of sand will not absorb any moisture from the cement mixture, one-half inch of sand shall be spread over the whole surface, and in case the work is subjected to a hot summer sun, an occasional sprinkling, sufficient to dampen the sand, should be followed for two or three days.

EXTRA MENTION.

Dry, sharp sand for this mixture is necessary without question or comment.

The first application should be thin in order that it may flow to the depth of the joints of the bricks, thereby insuring a substantial bond, and should be kept in constant motion while being applied, otherwise the sand will settle and you will have water and cement instead of water, sand and cement. The water and cement would not be objectionable, but the sand by itself is wholly so.

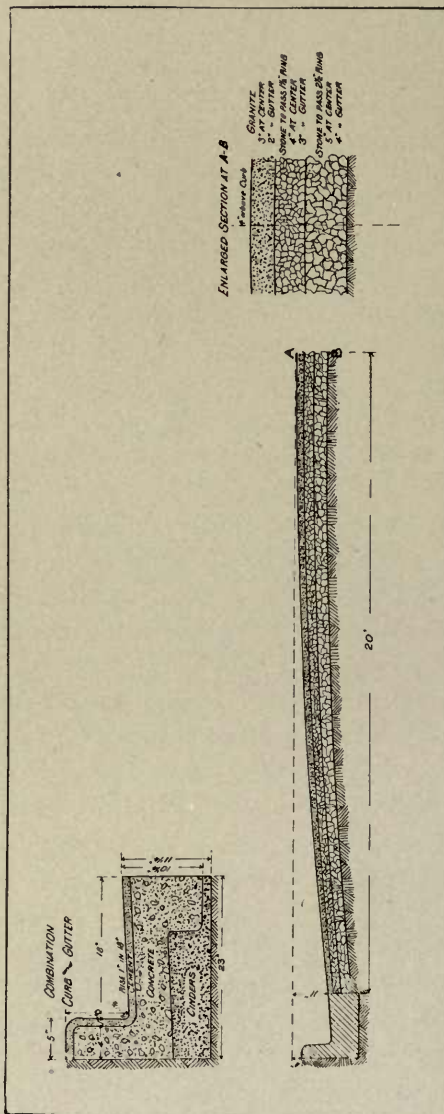
It must also be mixed in small quantities, as it is next to impossible to keep the sand in suspension when more than a common water pail of each, sand and cement, is used, and unless it is deposited upon the pavement with the sand in combination with the solution you will get the cement and water in the lower portion of the joints between the bricks and the sand without the cement in the upper portion. If you could get the sand in the lower, and the cement in the upper portion of said joints, you would have a good grouted street. Some one some day may perfect a mechanical device for doing this satisfactorily, but at this time no such method is known. The rocking trough has been tried for the mixing and discharging, but invariably the cement will flow out first, then follows the sand to fill the upper parts of the joints; therefore, the safest way is to use the scoop shovel as the specifications direct.

Ten days is the minimum time for keeping the street blockaded and free from traffic. Thirty days would be better, and longer if it were possible. In testing laboratories the usual time for allowing cements (neat cements at that) to stand before applying the tests, is twenty-seven days. Therefore, when you open a grouted street to traffic in ten days you are demanding and expecting more from the cement than any testing laboratory would, so the streets should remain closed as long as a suffering public will permit.

It is urgently insisted that in no case shall the proportion of cement be lessened. Grouting thus finished must remain absolutely free from disturbance or traffic of any kind for a period of ten days, at least.

Macadam and Other Broken Stone Pavements.—Pavements constructed out of broken stone differ considerably in the manner and details of their construction. Some follow the plan outlined by McAdam; others the specifications of Telford; and others are built upon no recognized plan. The difference between macadam and telford pavements is chiefly in the manner of constructing





A macadam pavement, showing usual type of cement combined curb and gutter. These illustrations are drawn to scale and may be followed in the construction of any pavement of this class.

the foundation. In the case of a telford pavement, the foundation consists of large fragments of stone laid on edge, lengthwise of the street, with the broadest side down. Telford, the originator of this pavement, specified that "The bottom course or layer of stones is to be set by hand in the form of a close firm pavement. The stones set in the middle of the road are to be 7 inches in depth; at 9 feet from the center, 5 inches; at 12 feet from the center, 4 inches; at 15 feet, 3 inches." * * * "All the irregularities of the upper part of the pavement are to be broken off by the hammer, and all of the interstices are to be filled with stone chips, firmly wedged or packed by hand with a light hammer, so that when the whole pavement is finished, there should be a convexity of 4 inches in the breadth at 15 feet from the center."

"The middle 18 feet of the pavement is to be coated with hard stones to the depth of 6 inches. Four of these 6 inches are to be first put on and worked in by carriages and horses, care being taken to rake in the ruts until the surface becomes firm and consolidated, after which the remaining 2 inches are to be put on. The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the piece in its largest dimensions may pass through a ring $2\frac{1}{2}$ inches inside diameter. The paved spaces on each side of the 18 middle feet are to be coated with broken stones or well cleansed, strong gravel up to the footpath or other boundary of the road, so as to make the whole convexity of the road 6 inches from the center to the sides of it. The whole of the materials are to be covered with a binding of an inch and a half in depth of good gravel, free from clay or earth."*

The so-called telford pavement of today differs in some particulars from that outlined above. In the first place, the subgrade is made to conform to the finished grade of the road before any of the stone is laid. The thickness of the foundation is usually uniform from curb to curb, and ordinarily does not exceed 6 inches. Upon the foundation there is laid a thickness of from 3 to 5 inches of broken stone, the pieces of which have a diameter of $1\frac{1}{2}$ to 2 inches. This is thoroughly rolled with a steam roller, after which 2 to 3 inches of a finer grade of crushed stone (1 to $1\frac{1}{2}$ inches) is added and the interspaces filled with screenings, after which the pavement is again rolled.

The use of large stones for the foundation to a broken stone pavement, is, in most places, unnecessary, and for this reason there has been a tendency not to use them except where the sub-

*Roads, Streets and Pavements, by J. Q. Gilmore.

soil is soft and miry. The telford and macadam pavements are used together in the United States, supplanting each other wherever the conditions admit of their economical construction. Many of the broken stone pavements in this country are neither macadam nor telford, and must not be confused with them.

No other kind of pavement requires a more careful consideration of the materials used or a better knowledge of methods of constructions than macadam or telford. In order to render the best service, a broken stone pavement must be constructed out of the best materials and in the most careful and painstaking manner. The kind of stone used, the thickness of the macadam and the width of the pavement all depend upon the nature of the subsoil, the climatic conditions and the amount and character of the traffic.

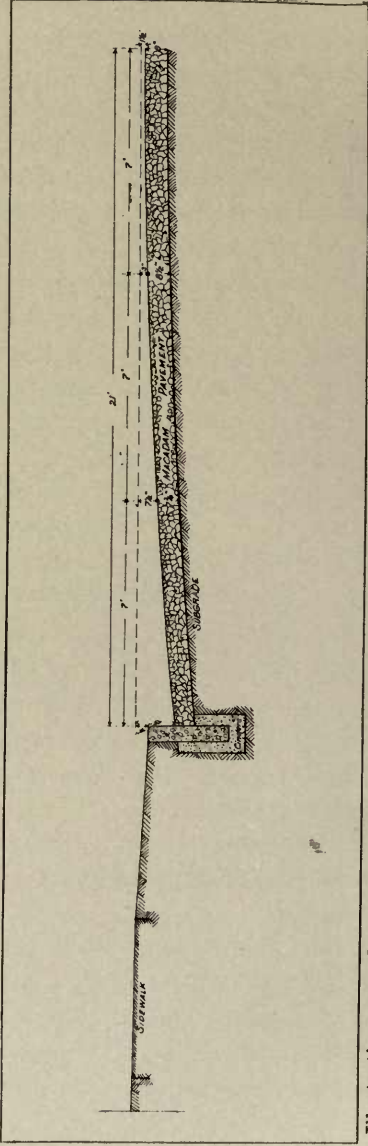
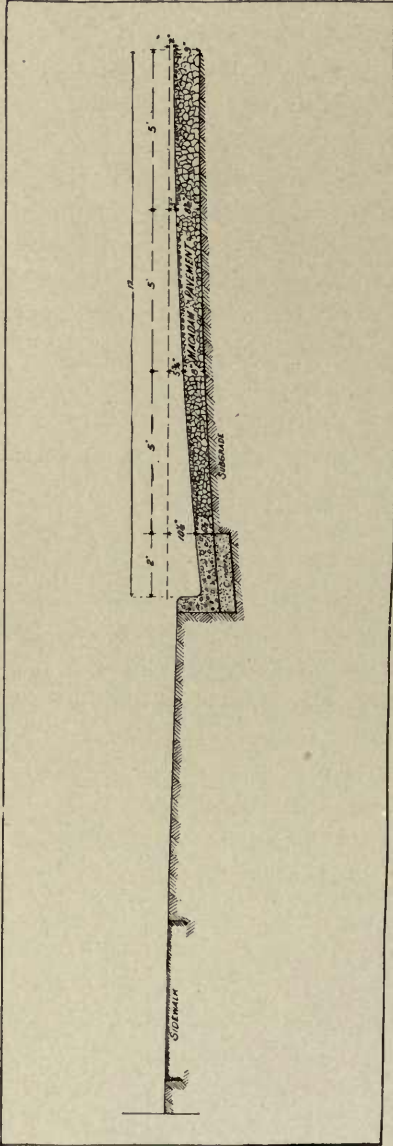
Not many years ago it was the practice to construct macadam pavements $2\frac{1}{2}$ to 3 feet thick, but today a thickness of 5 to 6 inches is often considered entirely satisfactory. A street on which traffic is sufficiently heavy to require a macadam pavement more than 10 inches thick, should ordinarily be improved with a block or brick pavement, not with broken stone.

In case the subsoil is sand or gravel, the problem of constructing a satisfactory macadam pavement is comparatively simple. The subsoil should be rolled until it is smooth and conforms to the shape of the finished pavement. If it is necessary to remove portions of the roadbed, refilling the same with gravel and sand, this portion should be thoroughly rolled after each addition of 3 or 4 inches of filling in order that there may be no unequal settling. The subgrade should be covered with 6 inches of broken stone, 2 to $2\frac{1}{2}$ inches in diameter. This should be well watered and thoroughly rolled. Before rolling, a sprinkling of screenings over the surface to fill the interspaces is considered desirable. After the first course is thoroughly rolled, 3 inches of broken stone 1 to $1\frac{1}{2}$ inches in diameter is spread evenly over the surface. This is well watered and rolled until perfectly smooth. A third course of $\frac{1}{2}$ to 1 inch of fine screenings is added, after which the pavement is again watered and rolled.

The thickness of the different courses must vary according to the subsoil, traffic and climatic conditions under which the pavement is constructed.

The foundation to a macadam pavement may be constructed out of almost any kind of rock. The wearing surface, however, should be constructed out of trap rock, rhyolite or granite.





Illustrating macadam pavements with and without cement gutter. These sections are drawn to scale and illustrate the relation of the different parts of a highway in both the vertical and horizontal dimensions.

The most abundant rock, and the one which has been used most extensively, is limestone. This stone wears much more rapidly than those mentioned above, and increases very materially the cost of maintenance. Limestone may be used with perfect safety for the foundation to a macadam pavement, but it is not as desirable as trap rock or granite. These, however, are sometimes too expensive to be used, in which case we are compelled to use a limestone. Limestones vary greatly in durability, and care should be exercised to use none but the best.

The best results are obtained from macadam pavements in cities where a proper system of maintenance has been established. It was never intended that a macadam pavement should wear without repair until reconstruction becomes necessary. It is expected that the top dressing of 2 to 3 inches will gradually wear away, but as soon as the larger pieces of stone, composing the course immediately underneath, show at the surface, the pavement should be redressed. The unevenness which results from large fragments at the surface soon produces ruts, which in time so mutilates the road as to require it to be entirely rebuilt.

Macadam pavements are objected to mainly on the ground that they are dusty or muddy and require constant cleaning and repairing to keep them in good condition. It is also claimed that the cost of repairs is out of proportion to the original cost of the pavement. However, the quantity of dust and mud depends chiefly upon the kind of stone used in the pavement and the amount and kind of traffic which passes over the pavement. The cost of maintaining a macadam pavement on a business street is usually excessive, on account of which other pavements are preferable. A macadam pavement on a residential street will be very satisfactory if properly constructed and placed under a proper system of street maintenance.

Tar, Bituminous or Bitulithic Macadam.—A pavement, consisting of a mixture of crushed rock and coal tar, called tar macadam, is being constructed in various cities in Canada and the United States. This pavement was first used about 30 years ago, and in some instances has proven eminently satisfactory. In 1901, Warren Brothers Company of Boston, Massachusetts, began the construction of a pavement known as bitulithic macadam. This pavement is built on principles which are the outgrowth of many years' experimentation with asphalt and coal tar products. It is built along practical as well as scientific lines, and gives evi-

dence of being very desirable for streets on which residential traffic prevails.

The value of this pavement, as shown by the experience of Hamilton, Toronto and other Canadian cities, depends chiefly upon the kind of stone, the quality of coal tar and the conditions under which the macadam is laid. A tar macadam pavement was laid on Mulberry street, Hamilton, Canada, in 1880, since which time it has required very little repair. This pavement had a 2-inch surface which was not entirely worn away after being in use for a period of twenty years. A pavement laid on Chestnut street, West Newton, Massachusetts, in 1874, is reported to have cost not over one-fourth of one per cent per square foot for repairs. Although the experience of some cities with this pavement has been unsatisfactory, yet it is thought possible to construct a bituminous macadam pavement which is superior to other sheet pavements in durability and less expensive in maintenance.

A tar macadam pavement may be constructed on a macadam, concrete or other foundation. It should consist of trap rock, rhyolite, quartzite or granite, mixed with sufficient sand and coal tar to completely fill the voids. The coal tar adheres very firmly to the hardest rock, and is intended merely as a bonding constituent. The wearing surface, which should be from 2 to 4 inches thick, is chiefly granite, quartzite or trap rock in pieces from one to two inches in diameter, cemented together with coal tar. The chief difficulty in constructing this pavement is to obtain the right quality of coal tar and in mixing it in correct proportions and in the right manner to give the best results.

The use of granite, rhyolite and quartzite for macadam is frequently objected to on account of the difficulty experienced in compacting these stones so as to provide a smooth surface. They do not bond as readily as limestone, but where a small quantity of limestone screenings is used very little difficulty is experienced. However, if the city can afford the additional expense of \$1.00 a yard to construct a bituminous macadam pavement, this pavement should be preferred. If it is expected to obtain the best results from this pavement, men who are experienced in handling coal tar and asphalt should be employed.

The coal tar on the exposed surface of the pavement will evaporate or oxidize, on account of which it may finally disappear from the pavement. It is expected, however, that even though this should happen, the usefulness of the coal tar as a bonding con-

stituent will have ceased. In such a case its oxidation will not be harmful to the pavement.

The following extract from a speech by Mr. Warren before a meeting of the Massachusetts Highway Association gives concisely the advantages claimed for the bitulithic pavement:*

"The bituminous macadam pavement is a combination of the most desirable features and principles of the ordinary macadam pavement and of the asphalt pavement. Our effort is to combine the desirable features of both, for both have very desirable features, and to overcome the weak features of both.

"We endeavor to get the foothold of macadam and to improve on the durability of asphalt, and, at the same time, to retain substantially the smoothness of the asphalt—that is, the general contour of the surface. The theory on which the construction is based is that of using crushed stone of varying sizes in certain definite proportions, the sizes varying in proportion, so that the finer sizes will fill the voids in the coarser and still finer voids, and so on from the size of a stone an inch and a half or two inches in diameter to an impalpable powder. Uniform sized stone will have voids of about 45 per cent. Ordinary sand will have voids of about 35 per cent., and the most dense sand which can be made by mixing two or more grades, will have voids of about 25 per cent. We combine the coarse and the fine particles, so that the finer will fit into the voids of the coarser, and thereby reduce the voids to 10 per cent., getting the maximum density of crushed stone. Then these materials, after heating the stone, are separated into varying sizes, and brought together in certain accurate proportions which would have been previously determined upon by laboratory examination and put through a mechanical mixer with a sufficient amount of bituminous cement to thoroughly coat the particles and fill all the voids so as to make a perfectly air-tight and water-tight concrete." *** "In general, the cost, allowing a reasonable profit, is approximately \$2.00 or \$2.25 a square yard,*** about a dollar a square yard over the cost of the macadam road."

Glass Blocks, Scoria Blocks and Slag Blocks.—These blocks have not been used very extensively in the United States, being found chiefly in European cities. It has been reported that glass blocks are being used to a considerable extent in Paris, France, chiefly on streets subject to heavy traffic. None of these blocks have been used in Missouri, and I do not know of any place in the United States where they are being manufactured.

There is an abundance of impure sand in this State out of which glass blocks might be manufactured, and it is possible that sometime this may be used in the manufacture of glass blocks for paving. The chief difficulty in the manufacture of these blocks is to secure the necessary toughness. The annealing process must be especially adapted to the purposes for which the blocks are to be used.

Miscellaneous Pavements.—These include, among others, granolithic, cobble stone, cinder, plank, log and charcoal. With the exception of the first named, they are all of a temporary nature, and their construction is confined chiefly to rural or suburban districts.

*Municipal Journal & Engineer, New York, June, 1902.

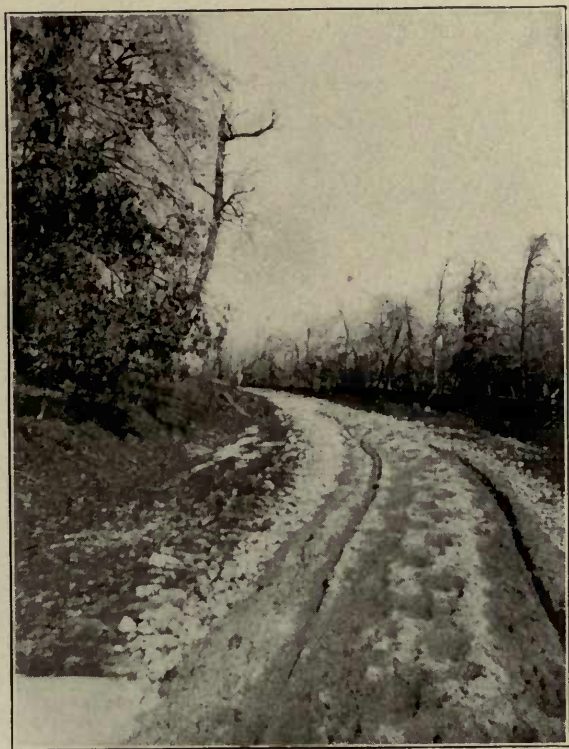
Granolithic or cement concrete pavements have been constructed in some cities, mainly in alleys. However, the nature of this pavement has been such as not to recommend it for general street surfacing. It is believed that a successful cement concrete pavement may, sometime, be constructed along the same lines as tar or bituminous macadam. Such a pavement will probably consist of different sizes of crushed rock, trap rock or quartzite, the voids being filled with Portland cement grouting in just sufficient quantity to bond the rock fragments together. The percentage of cement should not be enough to cause any danger from contraction and expansion through temperature changes. The pavement might be made in squares, leaving expansion joints along the curb and across the street. Such a pavement should be underlain with a sand cushion to relieve its natural rigidity.

Gravel.—This material is probably used more universally for the improvement of highways than any other. It is usually the cheapest road metal obtainable, and when used in generous quantities improves very greatly the conditions of a road which is either sandy or muddy. A graveled street is seldom as serviceable as a macadam pavement and is seldom suitable for heavy traffic.

Gravel varies greatly in quality, due to the kind of rock, shape and size of the fragments and the percentages of clay and sand with which it is mixed. The best gravel is composed of granite, trap rock, quartzite or flint fragments, which have angular outlines and are not over 2 inches in diameter, with an admixture of 10 per cent of sand and 20 per cent of clay. Out of gravel of this character, hundreds of miles of inexpensive and remarkably satisfactory pavements have been constructed.

Throughout the southern part of Missouri, there is an abundance of flint gravel, some of which contains the desirable proportions of clay and sand. Stream gravel is usually clean and free from sand and clay, while that which occurs on ridges or hill-sides is usually mixed with a varying percentage of clay. The former is most suitable for concrete, the latter for pavements.

Where gravel is used to improve a road, it should be spread evenly over the surface in courses three or four inches in thickness. Each course should be rolled thoroughly until it is hard and well compacted. In case the gravel lacks the desired proportion of clay, the addition of 25 or 30 per cent of fine crushed stone will often assist very greatly in bonding. In case the gravel contains no clay, the crushed stone should be added and thoroughly mixed,



Improving a county road with broken stone and chat,
Nov., 1906. Farmington-DeSoto Road, St. Fran-
cois County.



otherwise it may be impossible to bond the pebbles of which the gravel is usually composed.

Stone Blocks.—A street on which there is heavy traffic is the only one for which stone blocks can be recommended. These blocks may be made out of any kind of rock which is strong and durable. Limestone, granite, quartzite and rhyolite have been used very extensively. In some cities, such as Kansas City, Denver and Pittsburg, a hard sandstone, which might be called a quartzite, has been used for paving. Limestone blocks have, as a rule, proven unfit for this use. They are soft and do not wear well under the heavy traffic which it is intended that block pavements should withstand.

Any stone used for block paving should be free from parting planes, large flakes of mica or large crystals of feldspar. The stone should be medium grained and homogeneous, and composed of the most durable minerals, interlocking in such a manner as to impart strength to the stone. Blocks should have a rectangular shape and should be from three and a half to four inches in width, six inches in depth and eight to ten inches in length. The top and bottom surfaces should be smooth, and when laid the joints at the ends and sides should in no case be more than $\frac{3}{8}$ of an inch in width.

In laying a block pavement, the blocks should be embedded in a sand cushion and laid lengthwise across the street, except at street intersections, where they may be laid diagonally, or in such other manner as the city engineer may direct. Each course should be uniform in width, and the joints should be broken by a lap of not less than three inches. No broken or chipped blocks should be used. The finished surface of the pavement should be made to conform to the desired crown of the street. The joints may be filled with dry, clean gravel and sand or with asphaltic or Portland cement mortar, as described in the case of brick pavements. After the joints are filled with sand and gravel, they should be rammed to a firm and uniformly smooth surface. In case an asphaltic cement mortar is used, the joints should be first filled with sand and gravel, and the mortar applied to the pavement at a temperature of not less than 280° Fahr. At least three gallons of this mortar should be used to each square yard of the pavement. After the mortar has been introduced, and while it is still hot, the pavement should be covered to a depth of not less than $\frac{3}{4}$ of an inch with fine, clean gravel not exceeding $\frac{3}{8}$ of an inch in size. Such

gravel should be washed, dried and heated before being applied, in order to prevent the cement from being chilled.

As in the case of brick pavements, it is sometimes customary to lay from five to ten rows of blocks next to the curb lengthwise of the street to serve as a gutter. Two or three rows next to the curb may be elevated to keep the water away from the curb. Expansion joints should be left on each side of the street, next to the curb, and at intervals of about fifty yards, crosswise of the street. These joints should be about an inch in width and filled with coal tar pitch to within an inch of the surface. Broken blocks should not be used except where it is necessary to break joints.

It is customary to use an asphaltic cement mortar to fill the joints of stone block pavements. It is thought, however, that Portland cement grouting used in the same manner as described in connection with brick pavements would be equally, if not more, desirable.

Wooden Blocks.—The larger cities in this State have had some experience with wooden block pavements. Both cylindrical cedar blocks and rectangular, long-leaved yellow pine blocks have been used. They have been used in the natural state and after being treated with a preparation for preserving them. It is needless to say that the cedar block pavement has proven unsatisfactory. It is expensive, dusty, unsanitary and disagreeable to ride over. This pavement has been laid, as a rule, either on a plank or sand foundation, both of which are poorly adapted to this pavement and have hastened its deterioration. These pavements might have been more durable had they been laid on a concrete foundation.

One of the chief objections to the cedar block pavements, as constructed, is the heterogeneous size of the blocks. None of them are interchangeable, and wherever a portion of the pavement is taken up for repair, it can not be relaid without refitting the blocks. Another serious objection to this pavement, is the capacity which the cedar block has to absorb water and thereby expand. On account of this liability to expand, bituminous cement has been used in preference to all others. It is elastic, and attaches itself securely to the wooden blocks. It also obviates the necessity of introducing expansion joints, which would be required in case the interspaces were filled with Portland cement mortar. Attempts have been made to render cedar blocks impervious by a process called creosoting, but this has not proven altogether satisfactory. Various other processes, such as burnettizing and kyanizing, have

been tried with wooden blocks, but these have not resulted in a satisfactory pavement.

The modern wooden block pavement is constructed out of a rectangular block of Georgia or long-leaved yellow pine. Tamarack, mesquite, cypress and juniper have also been used less extensively. The rectangular block is made three to four inches in depth, and from five to ten inches long. They are sawed so that the fibre of the wood runs in the direction of the depth, and all sap wood, bark, decayed spots or knots are rejected.

As now used, wooden blocks are thoroughly dried by heating in an air-tight chamber and, while in a vacuum of from 15 to 20 inches of mercury, are treated with a heavy creosote oil admitted to the cylinder under a pressure of at least 60 pounds per square inch. The blocks are allowed to remain in the cylinder until they have absorbed at least 12 pounds of oil per cubic foot of timber, or until the oil shall have impregnated the entire thickness of the block.

The blocks are laid lengthwise across the street, or at different angles with the curb, as specified by the city engineer. The courses should be laid parallel, and the blocks be driven close together. Joints should be filled with a paving mixture consisting of 15 per cent. of Trinidad asphalt, 85 per cent. of coal tar paving cement, distilled at a temperature of from 200° to 250° Fahr., and should only be applied when blocks are thoroughly dry. It has been suggested that the joints be filled to within about 3 inches of the surface with asphalt paving cement, and that the remaining space be filled with Portland cement grouting. The Portland cement would in this case, protect the asphalt from the oxidizing influence of the atmosphere, and at the same time provide a surface which would more effectually resist abrasion. In case adequate expansion joints are provided for the expansion and contraction of the pavement, it might be preferable to entirely fill the joints with Portland cement grouting. Under ordinary conditions expansion joints should be provided near the curb lines, and at intervals of 200 feet across the street. After the pavement has been laid, it should be covered with about one-fourth of an inch of clean sand, which may be removed later by the contractor.

A pavement, which is constructed along these lines, is very desirable for residence streets. Along such streets it would undoubtedly prove very satisfactory. In the business portions of a large city, the traffic is too heavy for such a pavement.

It must be borne in mind at all times, that we are unacquainted

with any process by which wooden blocks can be rendered impervious for a period longer than six or eight years. In their natural state, wooden blocks absorb the excretions from horses, becoming moist, slimy and covered, below the surface, with a growth of fungus, rendering the pavement unsanitary. If a wooden pavement is used it should be made as nearly impervious as possible. Both the surface of the blocks and the interspaces between the blocks should be so treated as to shed all the water which falls on the street.

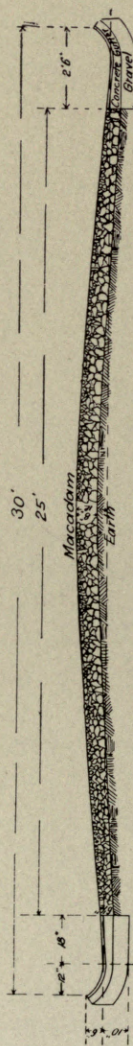
CURB AND GUTTER.

Every street, which is fully improved, has on each side of the pavement, a curb and gutter. These may be combined or separate. The gutter may also be made a part of the pavement, and the curb may be made a part of the sidewalk. The curb and gutter are sometimes laid before the street is paved, and at other times afterward. The gutter may be built out of any of the materials of which the pavement is constructed. The curb may be built out of wood, stone, cement or burnt clay. In the case of a macadam pavement, cement is usually used for both the curb and gutter. Sometimes the gutter is built out of stone, asphalt or brick, and the curb out of cement or stone. In the case of stone block, brick and asphalt pavements, the gutter is usually built out of the same materials as the pavement. The curb, however, is usually cement or stone. In the case of wooden block pavements, the gutter should be stone, brick or concrete, and the curbing the same as in the case of other pavements.

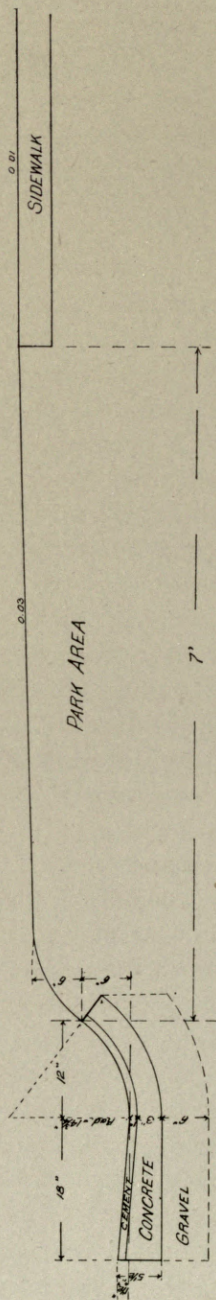
Limestone, granite, rhyolite and sandstone, are the principal varieties of stone used for curbing. Of these the granite and rhyolite are most durable. The corner curbs should consist of one piece of stone cut to such a radius as may be directed by the engineer. The slabs should be at least 3 feet long, 6 inches in thickness, and of a depth that will carry them from the level of the sidewalk to 6 inches below the finished sub-grade of the street. That part of the curb which is above the level of the street should be squared and dressed, so that when the different lengths are laid, one against the other, the joints will not exceed one-eighth of an inch in thickness.

All stone curbing should be laid upon a concrete foundation, similar to that which is used for foundations to brick and other pavements. This foundation should be six inches deep and twelve inches broad. Back of the curb, concrete similar to that used in





Cross Section of Street



Cross Section of Gutter and Sidewalk

A desirable method of constructing a macadam pavement and cement gutter, showing the adjacent park area and sidewalk. Note especially the gutter and the manner in which it is joined to the park area.

the foundation should be laid six inches wide to a depth of ten inches. The curb should not be put in place until the concrete in the foundation has set. After the curb has been set, all open spaces, either in the end joints or back of the curb, should be filled with cement mortar or concrete. Such mortar should consist of one part of Portland cement and one part of clean, sharp sand. Should this method of construction prove too expensive, sand, gravel or cinders may be substituted for the concrete. The sand, cinders or gravel should be laid to a depth of six inches, and thoroughly tamped. Back of the curbing, a space of from six to ten inches should be filled with gravel or cinders. A single flat stone should be embedded in the foundation underneath each joint to support the ends of the adjacent curb stones. The upper surface of these stones should be smooth, and each stone should support an end of two adjacent lengths of curb.

In case a combined cement curb and gutter is to be used, the earth should be excavated to a depth of twelve inches below the under surface of the gutter. The sub-soil should be thoroughly compacted by wetting, rolling or ramming, and covered with a seven-inch layer of clean cinders or gravel. Upon this foundation a layer of concrete, made up of one part of Portland cement, three parts of clean, coarse sand, and five parts of clean broken quartzite, granite or rhyolite, composed of pieces one to one and a half inches in diameter, should be spread. The gutter part should be four inches in thickness and the curb six inches. The height of the curb should conform to the grade of the sidewalk. Before the concrete has set, a layer of cement grouting, composed of one part of Portland cement and one and one-half parts of fine crushed granite or similar screenings, should be added to the surface. This layer should have a thickness of one inch, and should be smoothly troweled to conform to the desired grade. The smoother the surface of the gutter, the more efficient it will be in removing the surface water.

The combined cement curb and gutter should be made in sections ranging from three to five feet in length. The edge of the block should be made parallel to the length of the street, and the line of junction of the gutter with the pavement should be one-half to one inch below the grade of the finished pavement.

The combined curb and gutter constructed on the plan outlined, is well suited to all streets, except those having park areas. In the case of such streets, a well constructed gutter having a depth of from five to six inches, and a breadth of from thirty to thirty-

five inches, meeting and conforming to the grade of the grass plot on one side and the crown of the pavement on the other, is less expensive and more desirable. This style of gutter is especially recommended where asphalt, wooden block, macadam or vitrified brick pavements are constructed on residence streets.

The width and depth of a gutter should depend upon the maximum volume of water which it will be called upon to carry. In case the gutter is on a somewhat steep grade and the street has a considerable tributary area, the gutter should be made wider at the bottom than at the top. In case the roadway is winding and the grade steep, underground storm water sewers should be constructed to carry the water away to prevent flooding the pavement. Wherever there is a turn in the roadway sufficient to divert the water from the gutter into the street, an inlet should be provided which will carry the water from the gutter to the underground sewer. Macadam pavements are frequently injured by water overflowing from the gutter, which should be taken care of by inlets leading to storm-water sewers. One of the greatest defects in our gutter systems is a tendency to make them all of the same size, regardless of the volume of water which they are called upon to carry. Another mistake is the construction of the combined curb and gutter along streets where the gutter alone is necessary. A third mistake is the neglect to provide underground sewers to carry off the surplus water.

The following are copies of specifications in use in the cities of St. Joseph, Kansas City and Jefferson City, for the construction of artificial stone curbs and gutters.

JEFFERSON CITY.

Foundation—The foundation shall be not less than 8 inches of cinders, thoroughly wet and tamped to an even grade. The cinders must be free from lumps, dirt, stone, ashes or other foreign material.

On this foundation, when properly prepared, the curb and gutter shall be constructed as follows:

The base shall be constructed of concrete, composed as follows: One part of best Portland cement and three parts of Joplin flint in sizes not to exceed $\frac{3}{4}$ ", and containing enough clean fine screenings to fill all voids.

The ingredients for each batch shall be carefully and accurately measured and the mixing must be done on platform or in boxes. The stone and cement shall have four dry and two wet mixtures in such manner as shall be directed by the engineer. This mass shall then be spread upon the foundation of cinders and shall be tamped until all interstices are thoroughly filled and to the satisfaction of the engineer.

Within twenty minutes from the time the base or concrete is laid, the finishing or wearing course must be added.

Finishing Course—The finishing course shall consist of one part of best Portland cement and one part of clean sharp sand or flint screenings, or part of both, as the engineer may require. These shall be mixed to a stiff mortar and laid to the depth or thickness shown on the plans and cross sections. The joints shall be smooth,

straight, uniform and perfect in appearance and at right angles to the line of work. All exposed surfaces must be troweled to form a smooth and even finish. The exposed ends and sides must be plastered with mortar, such as is used in the wearing surface. Any spalling or splitting off whatever of the finished surface of the work, either at the joints or in the body of the stone, or any cracks or map cracks or defective work of any character, will be sufficient cause for rejection, and any rejected stone must be removed and replaced with a new stone immediately.

No patching of any character will be allowed except under supervision of the engineer, and if allowed, must be done within twenty-four hours from time stone was finished, and shall be at contractor's risk.

The contractor must protect the work during the construction and until the surface is ready for use against the elements or damages from any cause.

The contractor hereby guarantees that said curb and gutter shall be of such perfect material and workmanship as to endure for a period of one (1) year after the completion and acceptance of said work, without showing settlements, cracks, discoloration or any other defects, and said contractor shall, during the time of said guarantee, remove such stone as may show any defects and substitute new work therefor when called upon so to do by the mayor or city engineer, and shall complete such work of replacing defective stones within thirty days after the issue of written notice so to do, and such new work shall, in every respect, conform to these specifications.

The contractor will be required to construct forms of such material and in such manner that the finished stone will in all respects be true to line and grade, and he will be required to use such tools and appliances and workmen as are necessary to secure first class work.

Any deviation from line or grade or inequalities of surface or imperfect workmanship or poor materials, of which the engineer shall be the judge, shall be cause for rejection of the work.

KANSAS CITY.

Artificial Stone Curbing—The specifications for artificial stone curbing shall be as follows: The artificial stone or concrete curb shall be six (6) inches in finished thickness and eighteen (18) inches in finished depth, with upper face corner rounded to a radius of two (2) inches. After the necessary excavation has been made along the line of the proposed curbing, there shall be laid a foundation of cinders twelve (12) inches in width and four (4) inches in depth; the bed of cinders must be thoroughly rammed to a true and even surface with a hand rammer weighing not less than fifteen (15) pounds. Upon this bed of cinders, after it is well moistened, shall be constructed a curb which shall form a solid mass divided every seven (7) feet, or as near as may be, of its length into separate sections; and the concrete portion of it shall be composed of the same material and laid in the same manner as specified for artificial stone flagging. A facing one half ($\frac{1}{2}$) inch in thickness shall be constructed on the top and street face of the curb for a distance of eight (8) inches from the top. This facing shall be composed of one (1) part of Portland cement and one and one-half ($1\frac{1}{2}$) parts of sharp well screened and cleaned Kaw river sand, and shall be carried up simultaneously with the concrete, being plastered upon the front boards of frames immediately previous to the placing of the concrete. After the removal of the frames the facing shall be neatly troweled to a true, smooth surface. The curb shall be protected from the sun and wind by canvas or plank covering, or sprinkled with water at least twenty-four (24) hours after completion. The finished curb shall be of uniform color, and sections which do not correspond with the remaining portion of the curb must be replaced. Any spalling, or splitting off whatever, of the finished surface of the curb, either at joints or in the body of the stone, will be cause for rejection, and any rejected stone must be immediately removed and replaced with a new one. No patching of any character will be permitted. Circular curb stones or returns will be constructed in the same manner and of similar material as straight curbs, with a ten (10) foot radius for street returns and a four (4) foot radius for alley returns, unless otherwise determined by ordinance.

CEMENT.

Cement—In the construction of artificial stone flagging, curbing or driveways, for which Portland cement is specified, the same must be a well known and standard brand, equal to the best foreign manufacture. It shall leave by weight a residue of not more than three (3%) per cent. on a No. 50 sieve and fifteen (15%) per cent. on a No. 100 sieve; the sieves being of wire cloth of No. 35 and No. 40 wire (Stubb's gauge), having 2,500 and 10,000 meshes to the square inch respectively.

Briquettes of neat cement one (1) square inch in cross-section shall develop the following ultimate average tensile strength.

Age 24 hours (In water after hard set).....	125 lbs.
Age 7 days (one day in air, 6 days in water).....	400 lbs.
Age 28 days (one day in air, 27 days in water).....	500 lbs.

ST. JOSEPH. MISSOURI.

Artificial Stone Curb—Artificial stone curb shall be constructed of Portland cement concrete of a thickness of not less than five (5) inches and of a depth of not less than twenty (—) (—), inches with the upper face corner rounded to a radius of one inch.

The curbing shall be constructed in sections (—) (—) feet in length or continuously as directed by the city engineer.

The necessary excavation shall be made along the line of the proposed curb to such a depth and width as will admit of a foundation of cinders twelve (12) inches wide and eight (8) inches deep under the curb. After the excavation is made and before the wooden forms are set for the curb, the cinders shall be placed in the trench; they shall then be thoroughly wetted and rammed with a rammer weighing not less than forty (40) pounds and brought to a true and even surface twenty (—) (—) inches below the top of the finished curb.

Upon this bed of cinders the forms for moulding the curb shall be firmly and securely set, and in no case will loose material be allowed to be put into the forms after they are set.

The material of which the curb shall be constructed shall consist of one (1) part of the best American Portland cement, two (2) parts of Kaw river sand and four (4) parts of clean, carefully selected Joplin flint, or the best, carefully selected, clean, hard limestone or crushed granite. No fragment of stone shall be larger than one (1) inch in its greatest dimension. These proportions shall be determined by measurement and shall be thoroughly mixed dry; enough water shall then be added to give it the proper working consistency and the entire mass again thoroughly mixed.

This mass shall then be at once moulded into the forms set by the contractor and shall be rammed until all interstices are thoroughly filled. Particular care must be taken, that the body of the curb is well rammed and consolidated and to have the surface lines exactly true to line, grade and cross section as directed on the plans. The plane of the top of the curb shall make with the face an angle of one hundred and two (102) degrees or such other angle as the engineer may direct, and the top shall be so set as to conform with the plane of the sidewalk. Immediately after the completion of the body of the curb and before the cement therein has had time to set, the finishing course shall be added, which shall extend along the top of the curb, over the outside or street face for a depth of ten (10) inches and over the inside for a depth of three (3) inches. This course shall consist of mortar composed of one (1) part of Portland cement and one (1) part of clean Kaw river sand; the mortar shall be neatly troweled to a uniformly smooth surface.

The contractor will be required to furnish boxes or suitable apparatus to be used in measuring the different materials composing the curb.

The curb shall be protected from the sun and wind by a canvas or plank covering or sprinkling it with water for at least twenty-four (24) hours after completion.

The finished curb shall be of uniform color. Any spalling or splitting off whatever of the finished surface of the curb, either at the joints or in the body of the stone will be cause for rejection, and any rejected stone must be removed and replaced immediately with a new one. No patching of any character will be permitted.



A WELL CONSTRUCTED CEMENT CONCRETE WALK, KINGSHIGHWAY,
ST. LOUIS, MO.

Circular curb stones or returns will be constructed in the same manner and of similar material as the straight curb and of such radius as the city engineer may require.

The contractor will be required to enter into bond to guarantee the curb for a period of five (5) years after the completion and acceptance of the work, against settlement, cracks, discoloration or any other defects due to bad materials or faulty workmanship which shall appear at any time within the period of guarantee.

SIDEWALKS.

In many of the towns and cities of this State, board sidewalks are still being constructed. In some places they are built out of one-inch pine boards, and in other places out of two-inch oak planks. In some instances they consist of two planks, twelve inches wide, laid side by side, while in other cases the boards are laid crosswise of the street, and are from four to eight feet wide. The width of the sidewalk should vary with the traffic on the street, and the distance from the business center. If one should start from one of the main thoroughfares in any of the cities of this State, he would pass over sidewalks which constantly decrease in width until he stepped from a single board to a narrow foot path. He would also notice a change in the materials from stone, cement or brick to wood, as the outskirts of the city were approached. In general, the conditions of traffic have been observed, but there are many instances where sidewalks have been built without regard to this important factor.

Along a business street, sidewalks usually vary from ten to twenty feet in width, while along residence streets, a width of from four to eight feet is usually adequate to accommodate the traffic.

In the construction of cement concrete (granolithic or granitoid) walks, the same cautions should be observed as in the laying of concrete foundations for brick or other pavements. The strip upon which the sidewalk is to be constructed should be excavated to a depth of eight or ten inches below the finished grade of the walk, and parallel to it. Soft, mucky material should be removed and replaced with clean sand, cinders or gravel, all of which should be thoroughly compacted by ramming or rolling. The sub-grade thus formed should be covered to a depth of four inches with clean cinders or broken stone. After thoroughly wetting this layer and compacting it by ramming or rolling, a layer of concrete, three and a half inches in thickness, should be spread over the surface. This concrete should be prepared as described under the construction of concrete foundations to pavements,—seven parts of broken stone to five parts of cement mortar, consisting of one part of cement to four parts of sand, are the usual proportions. It should be again

rammed or rolled, and before it becomes dry, another layer, one inch in thickness, composed of one part of Portland cement and one part of finely crushed rock, should be added. The surface should be troweled to a smooth surface, after which it should be corrugated with a broom. As in the case of the concrete curb and gutter, sidewalks should be laid in alternate sections not more than four feet long.

The chief objection to the cement sidewalk, is its slipperiness,, which can be lessened by grooving or corrugating the surface before the cement hardens.

The following are copies of the specifications adopted by the cities of St. Louis, Kansas City and St. Joseph, for the construction of artificial (granolithic or granitoid) sidewalks:

ST. LOUIS SPECIFICATIONS FOR ARTIFICIAL STONE SIDEWALKS.

FOUNDATION OF CINDERS.

After the ground for the superstructure has been prepared a foundation of cinders, eight inches in depth, when well compacted by ramming to an even surface, shall be placed on said prepared ground. Said cinders to be moistened before the granitoid pavement is placed thereon. The upper surface of the wood side strips shall coincide with the established grade of the walk, and shall be securely held in place by stakes at least eighteen inches long, and earth filled in and thoroughly rammed to the top of the side strips before the pavement is placed on the cinder foundation. The cinders used must be free from dirt or ashes or other foreign matter, and consist of pieces that will pass through a two-inch mesh.

GRANITOID PAVEMENT.

After the cinder foundation has been finished the granitoid pavement shall be laid in a good, workmanlike manner.

The same to consist of two parts: First—A bottom course, to be three and one half ($3\frac{1}{2}$) inches in depth. Second—A finishing or wearing course, to be one-half ($\frac{1}{2}$) inch in depth.

The bottom course shall be composed of crushed granite and Portland cement, which shall be mixed in the proportion of one part of cement and three parts of crushed granite; not less than one barrel of cement, weighing four hundred (400) pounds, shall be used to each thirty-six (36) square feet of sidewalk.

The crushed granite shall consist of irregular, sharpedged pieces, so broken that each piece will pass through a three-fourths of an inch ring in all its diameters, and which shall be entirely free from dust or dirt.

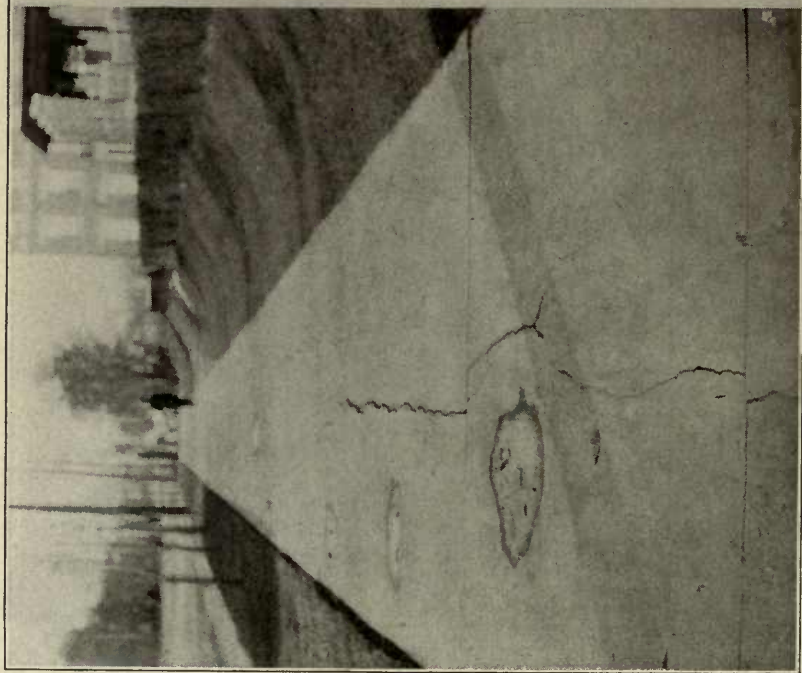
The crushed granite and the cement in the above mentioned proportions shall first be mixed dry, then sufficient clean water shall be slowly added by sprinkling while the material is constantly and carefully stirred and worked up, and said stirring and mixing shall be continued until the whole is thoroughly mixed.

This mass shall be spread upon the sub-foundation and shall be rammed until all the interstices are thoroughly filled with cement.

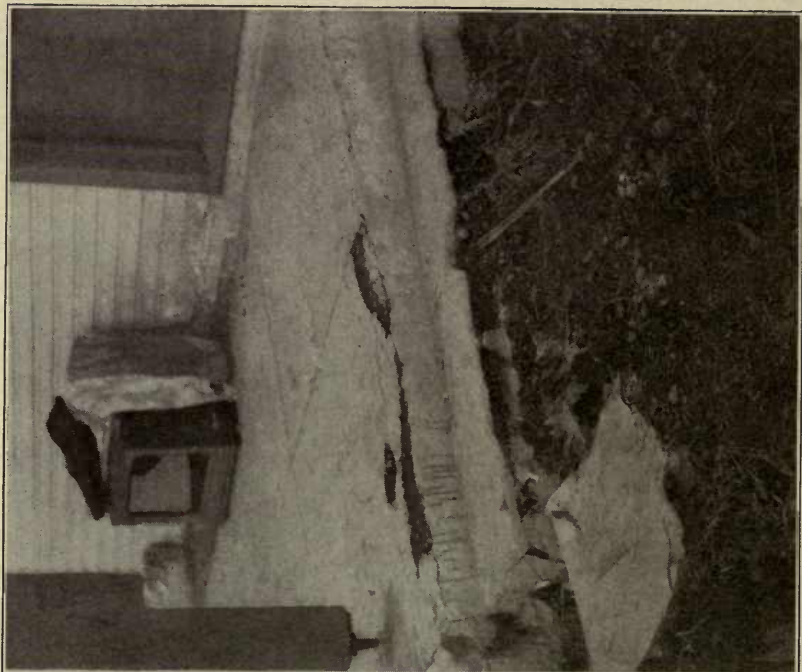
Particular care must be taken that the bottom course is well rammed and consolidated along the outer edges.

After the bottom course is completed a guage one-half inch deep shall be passed over it and the finishing or wearing course shall be added. This course to consist of a stiff mortar, composed of equal parts of Portland cement and the sharp screenings of the crushed granite, free from loamy or earthy substances, and to be laid to a





A POOR CEMENT CONCRETE SIDEWALK, PORT ROYAL, MO.



A POOR CEMENT CONCRETE WALK, ST. LOUIS, MO.

depth of one-half of an inch, and to be carefully smoothed to an even surface, which, after the first setting takes place, must not be disturbed by additional rubbing.

When the pavement is completed it must be covered for three days and kept moist by sprinkling.

METAL PARTING STRIPS.

The contractor will be required to use metal parting strips, four inches deep, three-eighths of an inch wide and of such length as may be directed by the street commissioner.

COLORING.

The wearing surface of the sidewalk pavement, when required, shall be mixed with such color or colors as the street commissioner may direct.

CEMENT.

The cement shall be Portland cement. It shall be newly made, fine ground, eighty-five per cent. (85 per cent.) shall pass through a sieve having ten thousand meshes to the square inch and capable of withstanding a tensile strain of five hundred pounds per square inch, of section when mixed pure, made into briquettes and exposed twenty-four hours in air and six days in water.

Briquettes made of one part by weight of cement to three parts by weight of Mississippi river or Meramec river channel sand, shall have a tensile strength of two hundred and fifty pounds per square inch of section when exposed twenty-four hours in air and six days under water.

All cement furnished will be subject to inspection and rigorous tests, of such character as the street commissioner shall determine, and any cement which, in the opinion of the street commissioner, is unsuitable for the work herein specified, will be rejected.

All cement shall be subject to tests for checking or cracking.

All cement shall be in well made barrels and branded with the name of the manufacturer. Samples for testing shall be furnished in such manner and at such times as may be required. All barrels accepted shall be marked, and the contractor shall carefully preserve these marks and not allow them to be imitated. The cement shall be kept under cover and dry until used, and any cement exposed to the weather after testing shall not be used. Cement may be re-inspected at any time when the street commissioner shall so direct, and if not found to be of proper quality, it shall be rejected. All rejected cement shall be at once removed from the work.

KANSAS CITY SPECIFICATIONS FOR ARTIFICIAL STONE WORK.

SIDEWALK.

Foundation—The sidewalk shall be properly graded and shaped to a depth of ten (10) inches below the intended surface of the pavement, and whenever loose, soft, spongy or loamy soil is found in the sub-grade it shall be removed to such additional depth as may be directed by the Board of Public Works, City Engineer, or their authorized agents, and shall be refilled with broken stone and earth, equal parts, and the whole sub-grade shall be well compacted by ramming. All refuse material shall be removed from the line of the work. After grading and shaping is done a foundation of cinders not less than six (6) inches thick shall be placed upon the sub-grade, which shall be well compacted by ramming to an even surface and well moistened before the concrete is placed thereon. Should rock be encountered in this sub-grade, this sidewalk shall be graded and shaped to a depth of nine (9) inches, made level and to a true grade and refilled with five (5) inches of cinders, well tamped and moistened.

Pavement—After the sub-foundation has been finished, the artificial stone flagging shall be laid in a good and workmanlike manner. This flagging shall be composed of fine Portland cement concrete and shall be laid in continuous stones, each section to be six (6) feet in length, and the sections are to be separated by a false joint, made with a groover, at least one and one-half (1½) inches deep and with an expansion joint at every third section. This expansion joint is to be made with steel templates

three-sixteenths (3-16) of an inch thick, and of the same length and depth that the stone is wide and thick, so as to entirely separate the adjacent stones. These joints must be smooth, straight and as small as practicable, and particular care must be taken to make them uniform and perfect in appearance; and shall be plumb throughout their depth and at right angles to the line of work. This pavement shall consist of two (2) parts. First—A base course three and one-half ($3\frac{1}{2}$) inches thick composed of Portland cement, sand, crushed Joplin flint, granite, or a hard native limestone, mixed by measure in the following proportions: Should crushed Joplin flint or granite be used, one (1) part of Portland cement, one (1) part of clean, sharp Kaw river sand, and four (4) parts of crushed Joplin flint or granite. Should native limestone be used, one (1) part of Portland cement, two (2) parts of clean, sharp Kaw river sand, and four (4) parts of hard, native limestone rock. The largest fragments of Joplin flint, crushed granite or native limestone rock, not to exceed three-quarters ($\frac{3}{4}$) of an inch in its greatest dimension, hard and perfectly clean, free from shale, dust or dirt and such fine particles that will pass through a No. 16 sieve, having 256 meshes to the square inch. The cement, sand and stone to be thoroughly mixed dry and then sufficient water is to be added so that when the mixture is spread and rammed, making a solid bed, the water flushes to the surface. Second—The finishing course to be laid upon the above described base shall be not less than one-half ($\frac{1}{2}$) inch in thickness, composed of one (1) part of Portland cement, one and one-half ($1\frac{1}{2}$) parts, of sharp, Kaw river sand, perfectly clean, free from dust, dirt or such coarse fragments that would be retained on a No. 8 sieve having sixty-four (64) meshes to the square inch, thoroughly mixed and skillfully laid. The finishing course must be spread on the concrete base and floated while the latter is still soft and adhesive, after which the surface will be smoothed and compacted by thoroughly and skillfully troweling at least twice before the cement is too hard for such finishing. The work must be kept moist and protected from the direct rays of the sun until perfectly set, and no concrete shall be laid when the temperature at any time during the day or night falls below 35° Fahrenheit. No re-tempering will be permitted and concrete which has already begun to set will be rejected.

The cement, crushed flint, or native limestone, or crushed granite and sand used in the construction of artificial stone must be proportioned by exact measurement, and for this purpose contractors will be required to provide themselves with rectangular boxes for measuring materials and a tight box for mixing. No mixing of materials on pavements will be permitted.

CEMENT.

Cement—In the construction of artificial stone flagging, curbing or driveways, for which Portland cement is specified, the same must be of a well known and standard brand, equal to the best foreign manufacture. It shall leave by weight, a residue of not more than three (3%) per cent on a No. 50 sieve, and fifteen (15%) per cent on a No. 100 sieve. The sieves being of wire cloth of No. 35 and No. 40 wire (Stubb's gauge), having 2,500 and 10,000 meshes to the square inch respectively.

Briquettes of neat cement on (1) square inch in cross-section shall develop the following ultimate average tensile strength.

Age 24 hours (In water after hard set).....	125 lbs.
Age 7 days (one day in air, 6 days in water).....	400 lbs.
Age 28 days (one day in air, 27 days in water).....	500 lbs.

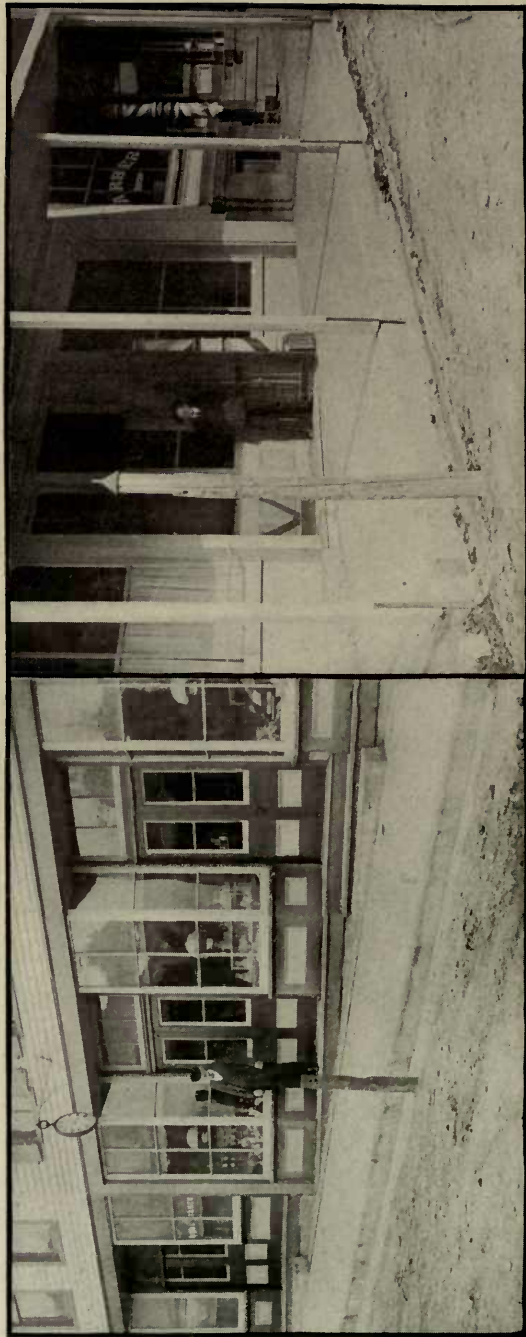
ST. JOSEPH, MISSOURI, HAS TWO FORMS OF SPECIFICATIONS FOR ARTIFICIAL STONE SIDEWALKS, WHICH ARE AS FOLLOWS:

Form A—These walks shall be composed of Portland cement concrete, constructed in alternate slabs or continuously as may be directed by the city engineer.

PREPARING SUB-GRADE.

The space to be occupied by the walk shall be properly graded to a depth of fourteen (14) inches below the finished surface of the sidewalk, and shaped with





SIDEWALK, GUTTER AND PAVEMENT, PLATTE CITY, MO.

vertical sides to receive the material. Any loose, soft, or unsuitable material found in the sub-grade shall be removed and the space filled with gravel, cinders, or fine broken stone, after which the entire surface shall be thoroughly compacted by ramming or rolling, and finished to the required grade and cross-section.

FOUNDATION.

Upon this sub-grade there shall be a layer of cinders which, after being thoroughly rolled or tamped, shall be eight (8) inches in thickness, and which shall be thoroughly moistened before the concrete is placed thereon.

BASE.

Upon the cinder foundation there shall be placed a concrete base five (5) inches in thickness, composed of the best American Portland cement: clean, coarse, sharp, Missouri river channel sand, and clean, hard limestone screenings, no piece or fragment of which shall exceed one and one-half inches in its largest dimension, and all mixed together in the following proportions: One (1) part of cement, two (2) parts of sand, and five (5) parts of screenings. The cement and sand in the above proportions shall be thoroughly mixed, dry, after which sufficient clean water shall be added to form a thin mortar; the screenings shall then be added, after first being wet, and the entire mass thoroughly and uniformly mixed.

WEARING SURFACE.

Upon the base as above described shall be laid a wearing surface one (1) inch in thickness, composed of equal parts of American Portland cement and Joplin flint, thoroughly mixed, dry, intelligently wetted and skillfully spread and rammed; this finishing must be spread on the base and floated while the latter is still soft and adhesive, after which the surface shall be smoothed and compacted by thoroughly and skillfully troweling before the cement is too hard for finishing.

Form B—These walks shall be composed of Portland cement concrete, constructed in alternate slabs or continuously as may be directed by the city engineer.

PREPARING SUB-GRADE.

The space to be occupied by the walk shall be properly graded to a depth of twelve (12) inches below the finished surface of the sidewalk, and shaped with vertical sides to receive the material. Any loose, soft, or unsuitable material found in the sub-grade shall be removed and the space filled with gravel, cinders or fine broken stone, after which the entire surface shall be thoroughly compacted by ramming or rolling, and finished to the required grade and cross-section.

FOUNDATION.

Upon this sub-grade there shall be placed a layer of cinders which, after being thoroughly rolled or tamped, shall be eight (8) inches in thickness, and which shall be thoroughly moistened before the concrete is placed thereon.

BASE.

Upon the cinder foundation there shall be placed a concrete base three and one-half (3½) inches in thickness, composed of the best American Portland cement, clean, coarse, sharp, Missouri river channel sand, and clean, hard limestone screenings, no piece or fragment of which shall exceed one and one-half inches in its largest dimension, and all mixed together in the following proportions: One (1) part of cement, two (2) parts of sand, and five (5) parts of screenings. The cement and sand in the above proportions shall be thoroughly mixed, dry, after which sufficient clean water shall be added to form a thin mortar; the screenings shall then be added, after first being wet, and the entire mass thoroughly and uniformly mixed.

WEARING SURFACE.

Upon the base as above described shall be laid a wearing surface one-half (½) inch in thickness, composed of equal parts of American Portland cement and Joplin

flint, or Kaw River sand, thoroughly mixed dry, intelligently wetted and skillfully spread and rammed; this finishing course must be spread on the base and floated while the latter is still soft and adhesive, after which the surface shall be smoothed and compacted by thoroughly and skillfully troweling before the cement is too hard for finishing.

Stone or brick sidewalks should be laid on a concrete foundation similar to that suggested for the cement concrete walk above described. Upon this foundation an inch of clean, sharp sand should be added for a cushion. Upon this, the brick should be laid crosswise of the pavement. To decrease the slipperiness of the walk, brick are now manufactured with corrugated surfaces. The same care should be used in the selection of the brick for sidewalks as in their selection for paving. However, the sidewalk does not require a brick which is so thoroughly vitrified.

Flagstones have been used very generally in this State. With the exception of sandstone, these become slippery with wear. It is frequently necessary to redress limestone and granite flagstones in order to destroy the slipperiness of the surface. Although sandstone is the safest for sidewalk use, it usually wears more rapidly than limestone and granite. A sandstone should neither be too soft nor too hard. One which is semi-indurated is considered best for sidewalks on business streets. A coarse grained granite is perhaps more desirable, although more expensive. Limestone is the cheapest flagging used for sidewalks, and on account of its greater strength, has been used in preference to sandstone.

Excepting in close proximity to quarries producing a first class flagstone, stone will probably not be used extensively in the future, owing to the introduction of the granolithic or granitoid walk.

There is no sidewalk but what will become slippery if covered with ice. Every sidewalk, sooner or later, may have depressions on its surface in which water will accumulate and freeze during the winter season. The accumulation of water on the surface may be reduced to a minimum by allowing a slope of about one inch in ten feet toward the gutter.

The color of the pavement may effect more or less its desirability in any particular locality. The reflection from a white pavement is very dazzling and sometimes almost unbearable during the extremely hot summer months. A black pavement absorbs a great quantity of heat during the day, making the surface often unbearably hot. The red and brown brick pavements absorb and retain a great quantity of heat, but are not as bad in this respect as those constructed out of asphalt. If our pavements could have

more of a greenish or grayish tint, they would be less objectionable from this standpoint.

CROSS-WALKS.

Cross-walks may be constructed out of any of the materials used in paving a street. The surface, however, should be smooth and on a level with the sidewalk at either end.

Cross-walks should be broad enough to accommodate the public and to keep the wheels from covering them with mud from the neighboring streets. There has been a tendency to construct narrow cross-walks with little or no crown, in order to minimize the cost. The public, however, will be best accommodated by wide crossings, having a gentle gradient toward the street on either side. In case the cross-walks are wide, the crown may be higher than in the case of an ordinary, narrow cross-walk, and yet be less disagreeable to drive over.

CHAPTER IV.

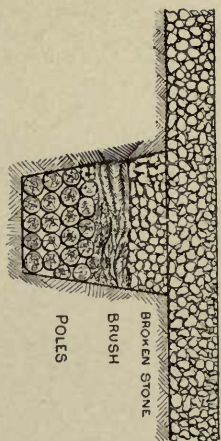
DRAINAGE.

A poorly drained road, not only increases the power necessary for moving loaded vehicles, but also involves an extra expenditure of money for maintenance. In improving a road, provision should be made for the removal of water which may find its way underneath the pavement, and also for the removal of that which flows off from the surface. Drainage channels must be provided on both sides of the pavement, and the pavement must be so constructed that the surface water will be carried off, without hindrance, into these channels. If this is done, a somewhat porous pavement may be made practically impervious. An uneven surface will collect the rain-water into puddles, which in time will saturate almost any common pavement.

In a discussion of street construction, we must recognize two classes of drainage, namely, surface and underground. The underground drainage is provided for the purpose of removing any water which may find its way into the pavement or the underlying subsoil. The surface drainage is provided for the removal of water flowing off from the surface by means of open gutters and underground sewers.

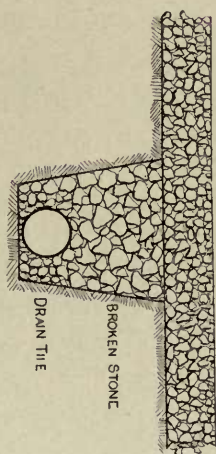
Underground Drainage—The removal of underground water is accomplished by means of underground drains. These may be laid either lengthwise or crosswise of the road. Longitudinal drains may be constructed either beneath or on both sides of the middle of the road. These drains may be built of broken stone, poles and brush, flag-stone or drain tile. They should be laid sufficiently deep to be out of danger of frost, and should be large enough to accommodate the maximum flow of water at any time of the year. They should be of such shape and should be laid in such a manner that the water passing through them will remove all earth which may chance to enter the pipe through the joints or otherwise.

It has been demonstrated that underground drains of this character not only assist in removing the surplus water from a muddy pavement, but also have a tendency to keep an extremely



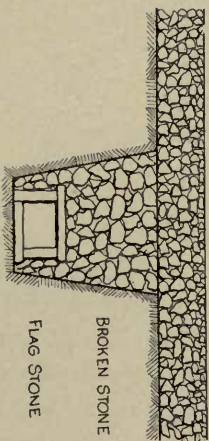
BROKEN STONE
BRUSH
POLES

POLE DRAIN



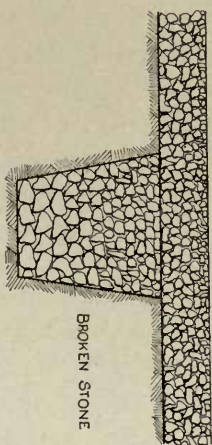
BROKEN STONE
DRAIN TILE

TILE DRAIN



BROKEN STONE
FLAG STONE

FLAGSTONE DRAIN



BROKEN STONE

BROKEN STONE DRAIN

TYPES OF DRAINS IN COMMON USE.



dry or dusty pavement moist through the* condensation of moisture from the air which circulates through them.

Surface Drainage—In a perfect system of storm water drainage, it is usually necessary to combine underground sewers with surface gutters. Whenever the accumulation of water in the surface gutters becomes so great as to require the construction of gutters which are out of proportion to the width of the street, they should be connected with underground sewers, through which the water may be carried outside of the city. Wherever the grades are steep, underground sewers are very necessary. Steep grades increase the velocity of the water multiplying its erosive power. This accounts very largely for the occurrence of deep gullies along many of the hillside country roads.

In cities where the domestic sewerage system empties by gravity into a lake or stream, the storm water may be carried into catch basins, and from thence into these sewers. The storm water flowing through these sewers at intervals, cleanses and purifies them to such an extent as to be very beneficial. In case the disposition of the sewerage necessitates pumping it, the storm water should be removed through a separate system of sewers.

Storm water sewers may be constructed out of cement, vitrified pipe, brick or iron pipe. They should be made water tight, and large enough to carry away the water received from the gutters. In order to secure a strong scouring action, a narrow base and broad top is desirable. The question of kind, size and depth, depend upon local conditions.

The gutter is essentially a part of the street pavement, and may be constructed out of any of the various materials used in paving. Brick, stone and cement concrete are the most important materials now used in the construction of gutters. The kind of gutters to be constructed depends upon the nature of the pavement. In the case of an asphalt pavement, a combination of brick gutter and stone curb is desirable. In the construction of brick pavements, the brick are usually laid up to the curb, in which case the pavement itself serves as a gutter to carry away the water. In this case it has been found desirable to lay ten to fifteen rows of brick lengthwise of the street, raising several rows next to the curb, in order to keep the water in a definite channel. In the case of a stone block pavement, it is usually unnecessary to provide a special gutter. The stone blocks being laid in the same manner as described for brick pavements. In the case of a macadam or telford pavement, a va-

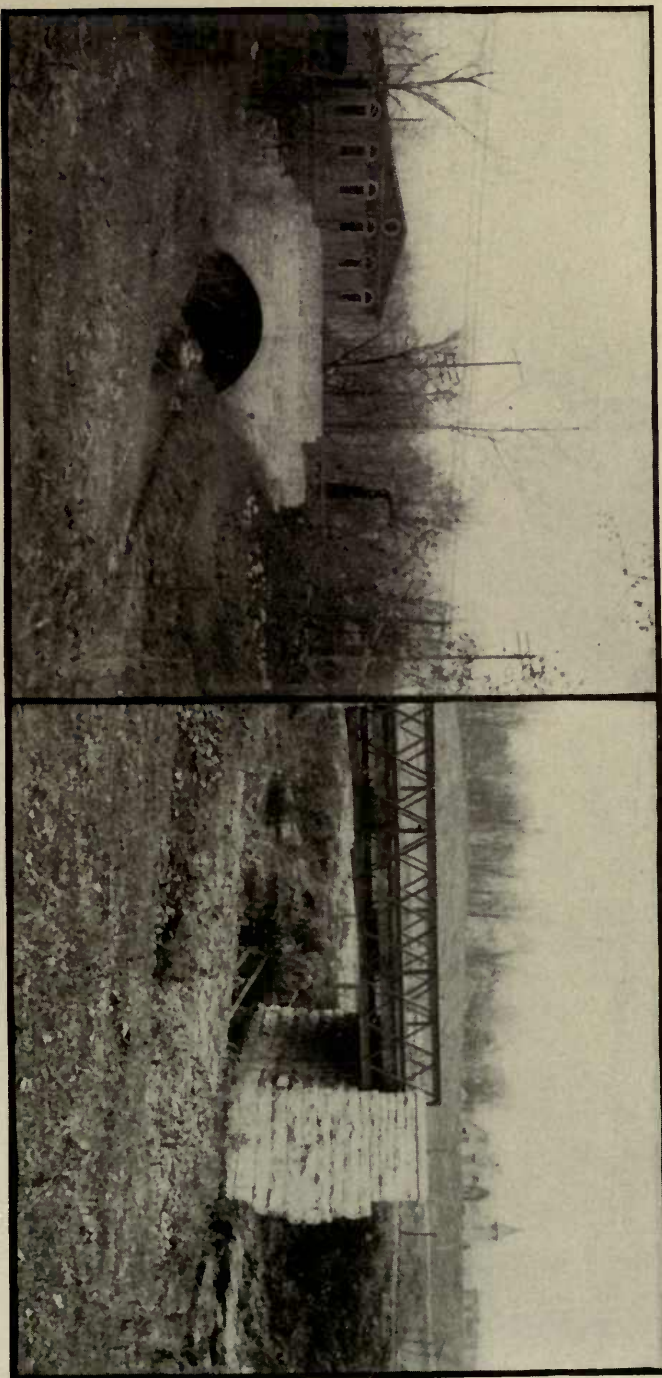
riety of gutters may be constructed. The most desirable is a cement combined curb and gutter, in which the manner of construction follows that employed in the building of artificial stone (granolithic or granitoid) walks. Asphalt, flag-stone and brick gutters each has its special advantage, depending upon the conditions under which it is used. The flag-stone gutter is, as a rule, the cheapest, and if properly constructed, is very desirable. However, as usually constructed, it has the disadvantage of collecting refuse and promoting the growth of vegetation, consequently looking untidy.

In the business sections of a city, it is necessary to construct a gutter which is durable and will withstand the stamping of horses tied next to the curb. In residence sections, this quality may be, in a measure, overlooked in favor of a gutter presenting artistic features, which may improve the general appearance of the street.

In residence portions of the city, a gutter may be constructed without the accompanying curb. This requires a modification of the usual shape of the gutter, as explained in the previous chapter. In any case, the gutters should be large enough so that they will not overflow during heavy storms. Gutters should not be made uniformly of the same size, but should be built in proportion to the amount of water which they will be called upon to carry.

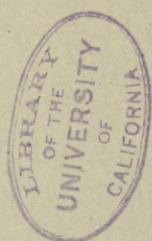
The culvert is a part of the surface gutter, extending under the pavement at the street intersection. In case the pavements are properly constructed, the surface water will be carried by gutters, which pass under the pavement next to the cross walks, or under the cross walk itself. At the present time, culverts are built chiefly out of sewer pipe, cement and brick. Wooden culverts are only a temporary expedient and should never be built, only in case of an emergency.

The method of constructing manholes, catch basins, flush tanks, lamp holes and valve boxes, is discussed in all standard text-books on street pavement. The only precaution which should be emphasized, is to see that the pavement around these openings is well protected by one or more rows of vitrified brick or stone blocks.

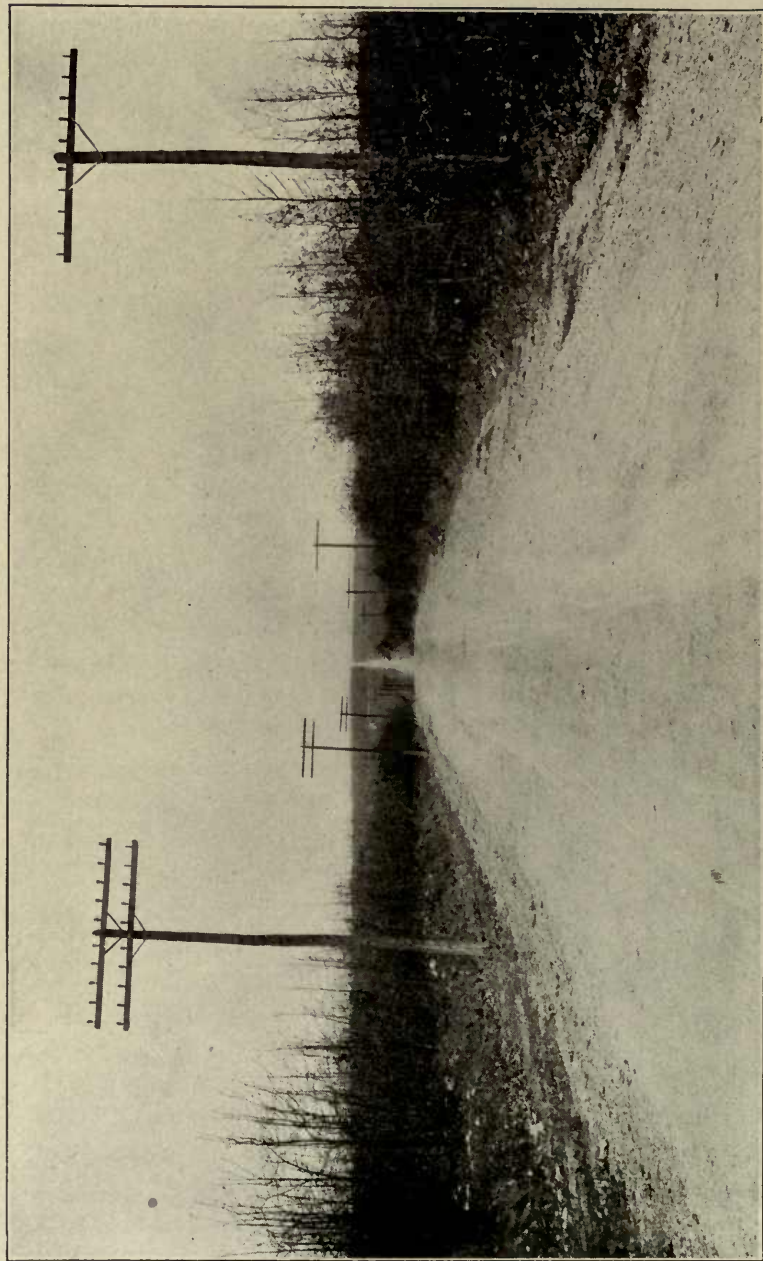


STONE CULVERT, NORTH ST. LOUIS, MO.

STEEL BRIDGE, WITH STONE ABUTMENTS, ST. LOUIS
COUNTY, MO.







A TYPICAL COUNTRY ROAD OF JASPER COUNTY, MO
Built out of Chat in 1904.

CHAPTER V.

COUNTRY HIGHWAYS.

The character of improvement which it is possible to make upon our highways depends chiefly upon the money which is available, with which to make such improvements. Under the present conditions it is necessary to distribute the money available over many miles of roads in order to make them passable. The funds for any particular road district cannot be applied to a few miles of road, but must be distributed over many miles. In fact, in many districts the revenue available is barely sufficient to patch the roads here and there where the storms have removed the culverts or washed deep gulleys.

Very few miles of macadam could be built in most road districts were the entire revenue applied to this purpose. The mileage that could be built in any district can be easily computed, when it is known that macadam costs not less than \$4,000 per mile. However, were the funds applied to the roads judiciously, they might be kept in equally as good repair as they are today, at a less cost. In this way a fund might be created for permanent improvements. With a judicious and intelligent expenditure of the entire fund available for road improvements, the highways might be vastly improved over what they are today.

As a rule, the people desire better roads, but there is a wide divergence of opinion as to how the improvements should be paid for. Some believe that those directly benefitted should bear the cost; others that the county should build the pavements; many believe that the State should bear the expense; while some would appeal to the National Government for aid. The only question to the individual appears to be one as to how he can obtain these benefits with the least tax upon himself. Were it possible to convince the people that permanent highway improvements, under any system of payment, would be a choice investment, we would have good pavements over a great part of the State.

It is thought that the State, the county and the individual, should each bear a part of the expense in proportion to the benefits which may accrue. This report, however, is not concerned with

the manner of raising revenue, but with the methods of improving and maintaining the highways.

DRAINAGE.

Under any system of road improvement good drainage is pre-eminently essential. Water which falls on the road must be quickly removed; that which falls on the adjacent land must be prevented from passing over the road; and that which finds its way into or beneath the pavement must be removed quickly. As has been explained in a previous chapter, running water is one of the most active agents in the destruction of paved and unpaved roads. Attention need only be directed to the gullies along the roads—on account of which they frequently have to be abandoned—to impress upon one the necessity of providing a method of removing the water.

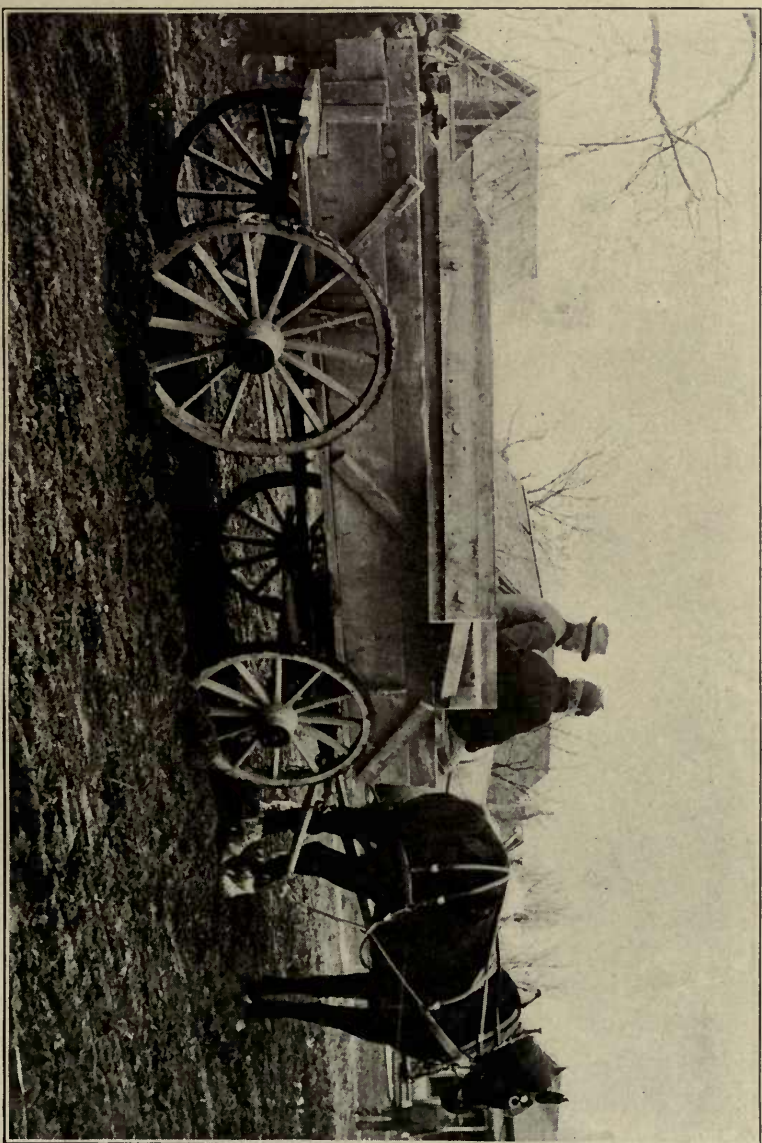
The injurious effects of water may be lessened in several different ways, (1) by lowering the grade of the road; (2) by rounding up the road toward the middle; (3) by preventing the water from crossing the road; (4) by making the surface of the road smooth; (5) by providing ditches or gutters on both sides of the road; (6) by laying drains underneath the road.

The erosive action of water increases with the declivity. By lessening the grade, the speed of the water flowing off the surface is lessened, and the harmful influence of rain water falling on the surface is decreased.

By giving the road a good crown, or by rounding it up well in the middle, the water may be quickly removed to the sides and into the gutters. The crown should not be unnecessarily high, but should be high in proportion to the steepness of the grade. It should also be higher in the case of dirt roads than in the case of any other kind. One foot in twenty feet has been recommended by most experts for dirt roads.

In order that the water may not be retarded in flowing off of the road, the surface should be smooth. A road with a rough surface not only collects the water and retards its flow, but it also contributes material which aids to the erosive action of the water.

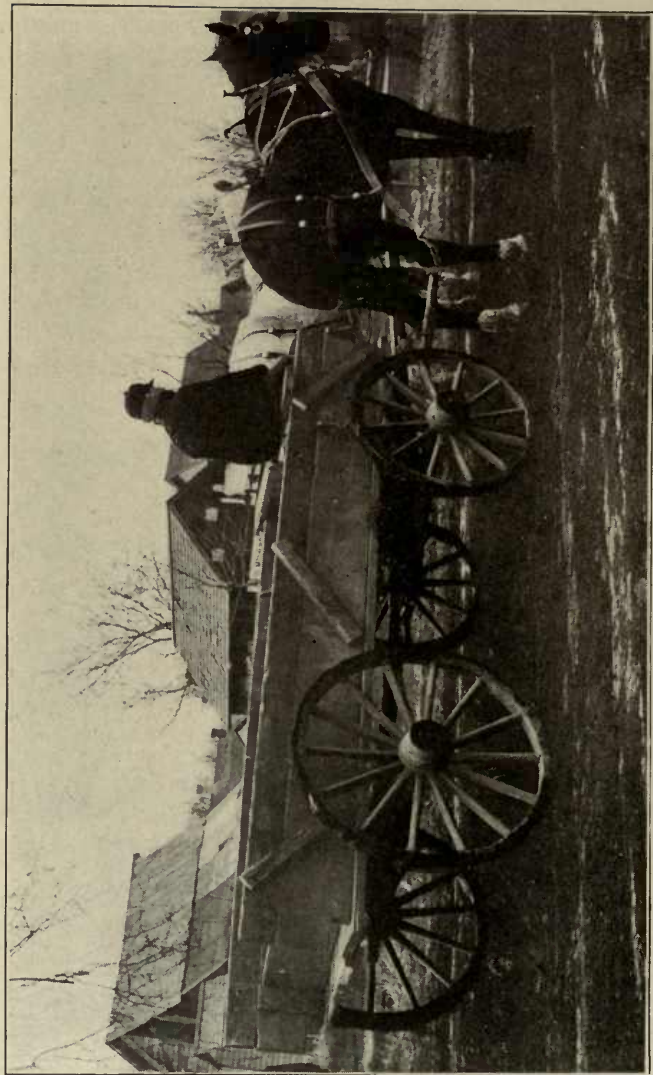
The water flowing off of the road should be carried into gutters on both sides of the road. These gutters should be large enough to hold all the water brought into them by the heaviest storms of the year. They should be broad and shallow and have flaring sides. The bottom should be covered with a layer of stone in pieces suf-



A DIRT ROAD BEFORE USING THE KING SPLIT-LOG DRAG.







A DIRT ROAD AFTER USING THE KING SPLIT-LOG DRAG.

ficiently large as not to be dislocated by the running water. This covering of stone will prevent the gutter from being cut deeper, and will also hinder the growth of vegetation, which often obstructs the ditches.

Water should not be permitted to cross the road from one gutter to the other. If it is necessary to transfer the water from one side to the other, it should be accomplished by means of culverts, built underneath the road. The construction of water-breaks, originally intended to throw the water from the road into the ditch, is now frequently used to carry the water from one gutter to the other. Water-breaks should never be built except on steep slopes, and then they should have a V-shape, the apex being on the up-hill side.

To remove the water which finds its way beneath the surface of the road, it is necessary to lay under-drains. These may extend lengthwise or crosswise of the street, and should be built out of drain tile, not sewer pipe. Wherever drain tile are too expensive, under-drains may be made out of stone, wood, poles, or brush, as shown in the accompanying illustration. The only cautions to observe are, 1st, give the drain a fall of six inches for each one hundred feet, distributing the fall evenly over the entire distance; 2nd, lay it deep enough to drain the entire width of the road; 3rd, use under-drains in case of heavy clay or loam soils and none in the case of sandy soils.

DIRT ROADS.

We will always have dirt roads, and for many years they will be greatly in the majority in this State. Were it possible to keep them smooth and hard during all seasons of the year, one could not wish for anything better. The one insurmountable objection is that they become soft after heavy rains, and teams passing over their surface break them up, leaving ruts and holes, which provide tracks in which the water travels. Dirt roads that are perfect during the summer months, often become impassable during the winter, as is well known by those living in the country.

For the farmers a road should be as good during the rainy season as at any other time. When the ground is wet and heavy from rains, the farmer cannot work his land, but were the roads solid and sound he could do his hauling. How often have you heard the farmer say, "I could not bring a load of hay to town because the rains have made the roads too bad." And the next time you see him he says, "I could not come to town after the roads dried up, because I had to work in the field." What a vast saving

of time to the farmer if the roads were passable at all seasons of the year.

But granted that we must have dirt roads, they can be so cared for as to minimize the length of time that they are impassable and admit of the hauling of loads of maximum weight.

In the maintenance of dirt roads attention should first be directed to the grade, which should not exceed one foot in twenty. Reducing the grade not only increases the load that it is possible to haul, but it also lessens the cost of maintenance. Attention should next be directed to "rounding up the road toward the middle." Dirt, as well as other roads, should be given sufficient crown to shed the water. The slope from the middle of the road to the sides should, under ordinary conditions, be about one foot in twenty. This will depend upon the grade.

Attention should next be given to the drainage, directions for which will be found in the first part of this chapter.

To prevent rutting, the grader, roller and split-log drag should be used. These are all the machinery required to make a smooth, compact surface on a dirt road. Scoops and plows should seldom be used on dirt roads.* They do not accomplish the desired results. Roads should be worked with grader and roller when the dirt is damp. If the dirt sticks to the roller, a thin layer of ashes, gravel or sand should be spread over the surface. This will prevent the difficulty. A five-ton roller that can be loaded with scrap iron, stone or water when an additional weight is needed, best serves the purpose.

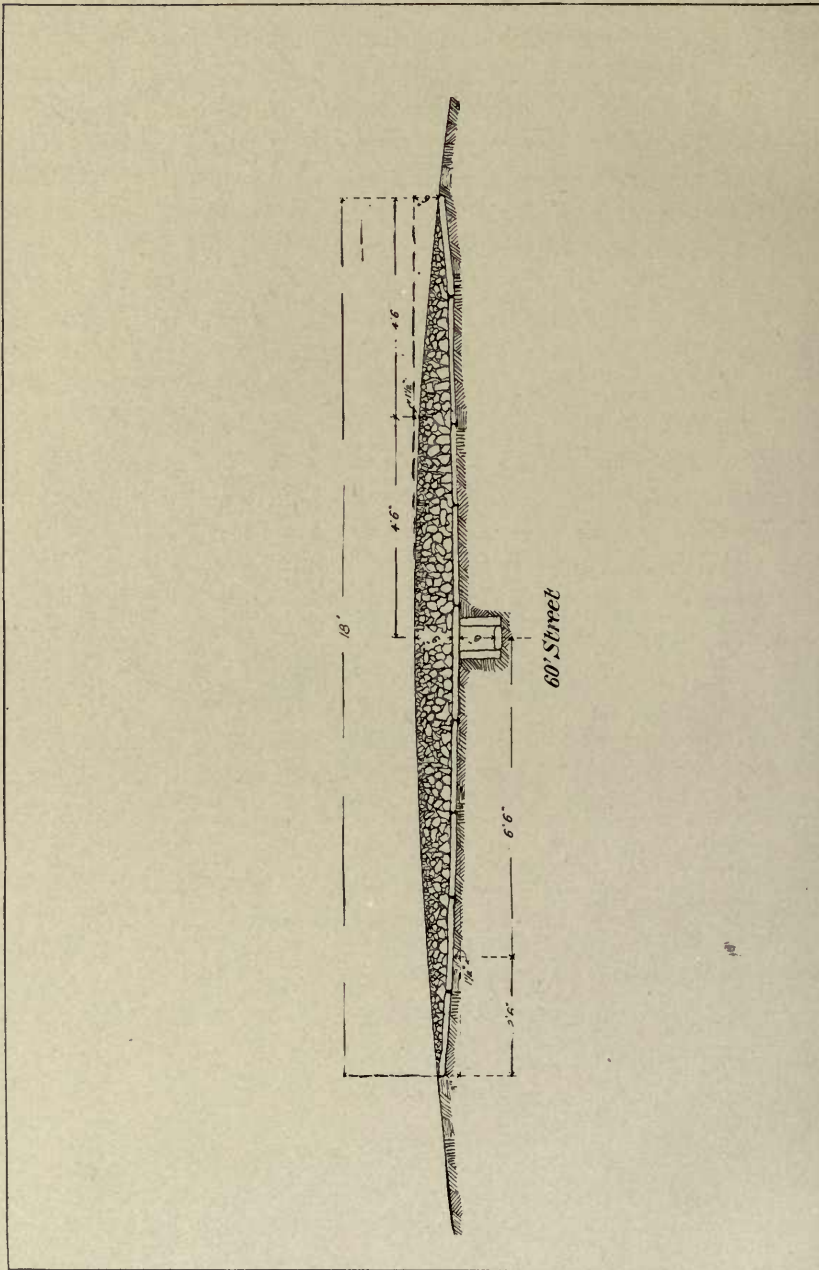
Ruts should never be filled with brush, sod or worn-out material scraped from the ditches. Neither should they be filled with large stone or gravel. Yet, everywhere, even in the towns and small cities, do we find this practiced. These materials may give temporary relief, but they result in producing such inequalities in the surface of the road as to make it on the whole worse than it was before these materials were added.

In the matter of maintenance, more attention is needed, perhaps, than elsewhere. The "Slip-log," or King drag,** is perhaps the most important device known for maintaining dirt roads. This drag is now being used over hundreds of miles of roads in this State, and the reports which we have received indicate that the dirt roads upon which it is used are the best dirt roads in the State. In the table given on the following pages, the reader may obtain

*See discussion relative to hardpan, further on.

**See appendix, page 113, for description of this drag, and instructions as to how it should be used.





A type of broken stone pavement, with drain running lengthwise of the street underneath the pavement. The foundation is a layer of flat stones. The remainder is broken stone, coarse at bottom and fine at top.

some idea of the extent to which this drag is being used. The accompanying illustration shows this drag as commonly built. It is usually attached to the wagon and drawn over the road by farmers on their way to and from town. The dragging is usually done during the summer and fall, after each rain. By constant and continued application of the drag it is possible to maintain the dirt road in excellent condition, except during the winter and spring. Daily and weekly attention to the roads is needed above everything else.

The use of wide tires on wagons will not only prevent the rutting of dirt roads, but will also assist very greatly in compacting the dirt. Wide-tired wagons act as rollers, and in this capacity are extremely valuable. In addition to this it has been demonstrated that less power is required to pull a wagon having wide tires than one having narrow tires. The introduction of wide tires has been heretofore retarded by the cost. This, however, has been, in a measure, eliminated by the introduction of the adjustable wide tire, which may be attached to any narrow-tired wagon. These tires cost \$2.00 each, making a total cost of \$8.00 for a set of four. The extent to which wide tires are used in this State is shown in the table accompanying chapter VII.

In this place attention should be directed to the fact that dirt roads may be improved and maintained in better condition than they are today if the farmer would give his attention, individually and collectively, to the use of those devices for road improvement which he can obtain at little expense. For any outlay which he may make, he will receive manyfold returns. In some sections of the State, the farmer fully lives up to his obligations in this direction, and his efforts should be fully recognized.

SAND ROADS.

Sand roads require a somewhat different treatment than dirt roads. They are best when wet, and almost impassable when dry. For this reason, they should not be drained. Every effort should be directed toward keeping them moist. Trees planted along the roadside assist in holding the moisture, and their planting should be encouraged.

The addition of clay often betters the condition of the road, provided it is mixed with the sand. The clay serves as a binding material which holds the sand in place, and it assists in retarding the evaporation of the moisture.

Where the sand is very deep it has often been advantageous to drain the water into the road. The writer has driven over sand

roads, upon which water was standing, which were firm and hard. This, however, depends upon the character of the sand.

Shavings from planing mills and shingle mills, when mixed with sand, serve as a temporary improvement. Sawdust is beneficial, but not as satisfactory as shavings.

Logs are frequently used on both clayey and sandy roads, chiefly the former. A road improved by laying short logs cross-wise is known as a corduroy road. This character of improvement often serves a useful purpose.

GRAVEL ROADS.

It is very well known that the weight of load possible for a horse to pull varies with the nature of the road surface. Ordinarily a horse which is capable of pulling one ton over an earth road, can pull two tons over a well-constructed gravel road, and four tons over a macadam pavement. For the size of load hauled over the roads in this State, see the table accompanying chapter VII.

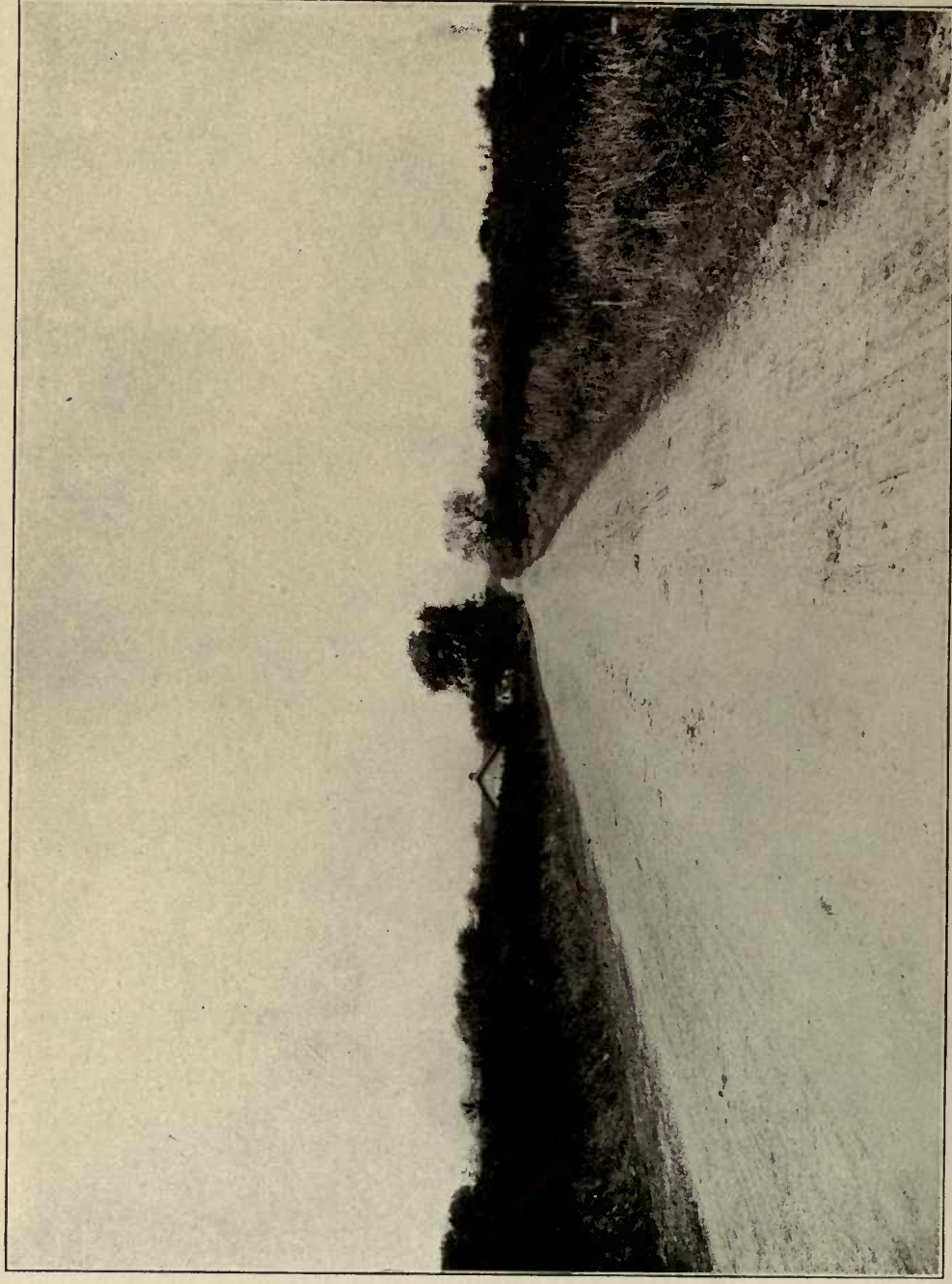
In the construction of a gravel road, special attention should be given to the nature of the gravel used. A lean, water-worn gravel is not desirable for surfacing roads. The fragments are always loose, rolling and slipping around under the wheels and hoofs of the horses. A good gravel for roads contains an admixture of clay and sand, sufficient so that it may be compacted into a hard, smooth surface. Too much clay is also harmful, and it is thought that from ten to twenty per cent. is amply sufficient.

The gravel should be angular, and none of the pieces should exceed two inches in their greatest diameter. Larger pieces are liable to work to the surface, injuring road.

The most abundant gravel in this State consists chiefly of flint (chert). Most of the stream beds in the Ozark region are covered with flint gravel, worn smooth by the action of the water. The hillsides are frequently covered with a talus of flint, clay and soil, the gravel being angular and of heterogeneous sizes. Frequently the gravel and clay form what is known as a hard pan. Where there is not too much clay, this hard pan constitutes a desirable material for surfacing roads. Some of the best roads in the State are over deposits of a similar character, occurring upon ridges, where the drainage is good.

There is usually considerable difficulty in grading a road which runs over a hard pan subsoil. It is necessary where this material occurs, to use a plow or "hard pan loosener." Where it is impossible to start a plow, the ground may be loosened by drilling holes six





CARL JUNCTION ROAD, JASPER COUNTY, MO., IMPROVED WITH CHAT IN 1901.

or eight feet apart and firing dynamite in them. Where hard pan roads are allowed to rut they are not easily repaired, because the material used for filling can seldom be packed as hard as the natural ground.

MACADAM ROADS,

Stone roads, of any character, are frequently called macadam roads. It is for this reason that many people are opposed to macadam. Frequently, I have been obliged to drive over a road which has been surfaced with large pieces of stone, often six inches in diameter, and I am sure that were I compelled to travel that road for six months I would prefer to fall through the mud for a life-time. But broken stone spread over a road is not macadam, although macadam is built out of broken stone.

A macadam pavement is superior to either gravel or dirt road. It is, or should be, good during rainy as well as dry weather. It should wear longer without repair, and repairs should be simpler and more easily made. By means of the grader, drag and roller, a dirt road can be made almost perfect during moderately dry weather, but they may be impassable when rainy. A macadam road is always firm, and travel becomes as easy during rainy weather as during dry weather.

The method of building macadam pavements is discussed in Chapter III. At this place, however, attention is called to the importance of using the best stone obtainable, even at an additional cost. Trap rock is the best. Then come granite, rhyolite, limestone and quartzite. Use the dust and fine screenings as a binder. Only use clay when absolutely necessary, as is sometimes the case when quartzite is the stone used. Roll the macadam well, until a small stone, placed on the surface, will be crushed before being driven in to the pavement.

The pavement should not be unnecessarily wide—ten to fifteen feet usually being adequate on most country roads. The pavement should not be unnecessarily thick,—six inches usually being sufficient to sustain the traffic from the country.

Eldridge says, "A 4 or 5 inch stone or gravel road will last longer without repair when wide tires are used than an eight or ten inch road of the same material on which narrow tires are used." This is a strong argument in favor of the use of broad tires and one which should command the attention of the farmer.

Macadam roads should be kept constantly in repair. They should never be permitted to wear out. As soon as the pavement

shows a weakness anywhere new material should be added. All loose stones should be removed from the surface, ruts should be filled as soon as they begin to form, and everything should be kept up to the condition of the road when newly paved. This can only be accomplished by establishing a system of maintenance such as is described in another part of this volume. (See chapter VIII.)

Under the New York Highway Commission macadam pavements nine feet wide are constructed at a cost of \$900.00 to \$1,000.00 per mile. Similar pavements 9 to 20 feet wide and 4 to 12 inches thick, in New Jersey, cost \$2,000 to \$5,000 per mile. In Rhode Island, 16 to 20 foot macadam pavements cost from \$4,000 to \$5,000 per mile. Gravel roads in New Jersey cost \$1,000 to \$1,300 per mile. From these figures one can readily understand that a State which enters into the business of building macadam pavements must appropriate millions of dollars, not thousands. Five hundred thousand dollars is merely a bagatelle. Five millions would make a beginning, but this amount would only build a thousand miles of macadam pavements—not over ten miles in each county. Whatever sum the State may appropriate, the counties in which macadam pavements are built and the property owners tributary to such roads should each contribute an equal share. In this manner it would be possible to construct 3,000 instead of one thousand miles, with a five million dollar appropriation.

CHAPTER VI.

MATERIALS IN MISSOURI AVAILABLE FOR HIGHWAY IMPROVEMENTS.

Among the important materials used in the improvement of the highways are stone, cement, sewer pipe, drain tile, vitrified brick and asphalt. All of these, with the exception of asphalt, can be obtained within the State. Asphalt, in the shape of asphaltic limestone and sandstone, also occurs in the State, but the deposits have not yet been developed.

Vitrified paving brick are manufactured in close proximity to the large cities where the chief demand for this material exists. The factories in Missouri are as follows:

Phoenix Brick and Construction Company, St. Joseph; F. Oberhouse, Washington; Kansas City Paving Brick and Tile Company, Kansas City, factory at Brownington; Kansas City Hydraulic Press Brick Company, Kansas City; Brookfield Paving Brick Company, Brookfield; Moberly Brick, Tile and Earthenware Company, Moberly; Hydraulic Press Brick Company, St. Louis; St. Louis Vitrified & Fire Brick Company, St. Louis, and the Laclede Fire Brick Manufacturing Company, St. Louis.

Asphalt is chiefly imported, and the construction of asphalt pavements is in the hands of a few companies. The bitulithic pavement is constructed chiefly by Warren Brothers, of Massachusetts. The coal tar used in this pavement might be obtained in this State. There is an abundance of stone, the granite of Southeastern Missouri being especially well adapted for use in this pavement.

The western and northern parts of the State are supplied chiefly with Kansas Portland cement, although that from the Atlas Portland Cement Company, at Hannibal, and that from the St. Louis Portland Cement Company at St. Louis are also used. The eastern and southern sections of this State use chiefly the cements manufactured at St. Louis and Hannibal. It is expected that very soon new cement factories will be in operation at Independence and Iatan, in the western part of the State, and these will occupy a portion of the field now supplied by the Kansas factories.

The price of Portland cement is, at present, very high, but the erection of new factories will tend to bring the price down, so that it will be within the reach of the people, and especially the smaller towns and cities that contemplate the construction of granolithic walks and other constructions in which cement is required.

Sewer pipe is manufactured by the following firms in Missouri:

F. X. Blanck, Boonville; W. S. Dickey Clay Manufacturing Company, Deepwater and Kansas City; Aug. Blanck, California; Blackmer & Post Pipe Company, St. Louis; Laclede Fire Brick Manufacturing Company, St. Louis, and Evans & Howard Fire Brick Company, St. Louis.

The Missouri sewer pipe is of excellent quality and finds a market far beyond the confines of the State.

Drain tile are manufactured by the following companies in Missouri:

J. M. Wolf, Tarkio; Frank Rist & Son., Lamar; Wm. McCubbin, Braymer; Jackson Brick and Tile Company, Jackson; L. S. Harding, Carrollton; Woodsen Brick Manufacturing Company, Carrollton; Ray County Coal Brick and Tile Company, Norborne; Creighton Clay Company, Creighton; Brunswick Brick and Tile Company, Brunswick; Hoffman & Company, Boonville; H. H. Wright, Maitland; W. S. Dickey Clay Manufacturing Company, Deepwater; Henry Bosselman, Concordia; Gottlieb Nieman, Alma; F. P. Canterbury, Higginsville; Wm. Nieman, Corder; Concordia Tile and Brick Company, Concordia; B. C. Magruder, Winfield; Brookfield Paving Brick Company, Brookfield; Chillicothe Brick and Tile Company, Chillicothe; Aug. Blanck, California; Versailles Fire Brick and Clay Manufacturing Company, Versailles; Anderson Craig, Maryville; W. G. Sayler, Burlington Junction; W. H. Sisson, Curryville; C. A. Zieher, Livonia; Laclede Fire Brick Manufacturing Company, St. Louis; Evans & Howard Fire Brick Company, St. Louis; H. Crouch & Son, Napton; Dulaney Bros., Slater; and George T. Meyers & Company, Memphis.

These do not supply the entire State, and numerous localities not now using tile will require them when a system of highway improvements is established. The demand for drain tile is now chiefly for agricultural purposes, and even for this purpose the consumption would be greatly increased were the factories in close enough proximity to the market.

In the case of cement, paving bricks, asphalt, sewer pipe and drain tile, as in other products, the quality varies. Some are suit-

able, others are not. For this reason, these materials should be fully tested before being used, so that the defective ones may be rejected. The large cities usually have their own laboratories, but for the country and the smaller cities and towns these tests might be made to advantage by the State, either by this Bureau or some other that is equipped with suitable machinery.

The most important material used for the improvement of the country roads is stone. Stone is used either in small fragments, classed as gravel, crushed stone and chat, or in blocks. Gravel consists of small pieces of stone which have been broken from larger masses by the forces of nature. These fragments are usually brought together by streams, in which case they form bars. They may, however, accumulate as a result of weathering, in which case they are known as residual deposits. Glaciers have also been instrumental in producing gravel and in bringing it together. Crushed stone is produced by breaking stone in a crusher or with a hammer. Chat, in reality, is finely crushed stone. It is rock which has been finely crushed in order to remove minerals, such as galena and zinc blende. Chat is frequently called tailings.

Stone blocks, when used for sidewalks, are usually called flag-stones; when used for curbing, curbstone; when used for gutters, gutter-stone; when used for pavements, stone blocks or Belgian blocks; when used for telford, rubble stone.

Missouri has stone, in abundance, suitable for improving the country highways. Trap rock, granite, rhyolite and dolomite in the southeastern portion of the State; flint, dolomite and limestone everywhere over the area south of the Missouri river, except in the northwestern part, which is underlain with the Coal Measures formation; limestone north of the Missouri river, east and west of the area underlain at the surface with the Lower Coal Measures formations; boulders and gravel of igneous rocks in the glacial drift north of the Missouri river; and stream and residual gravel over a greater part of the State south of the Missouri river.

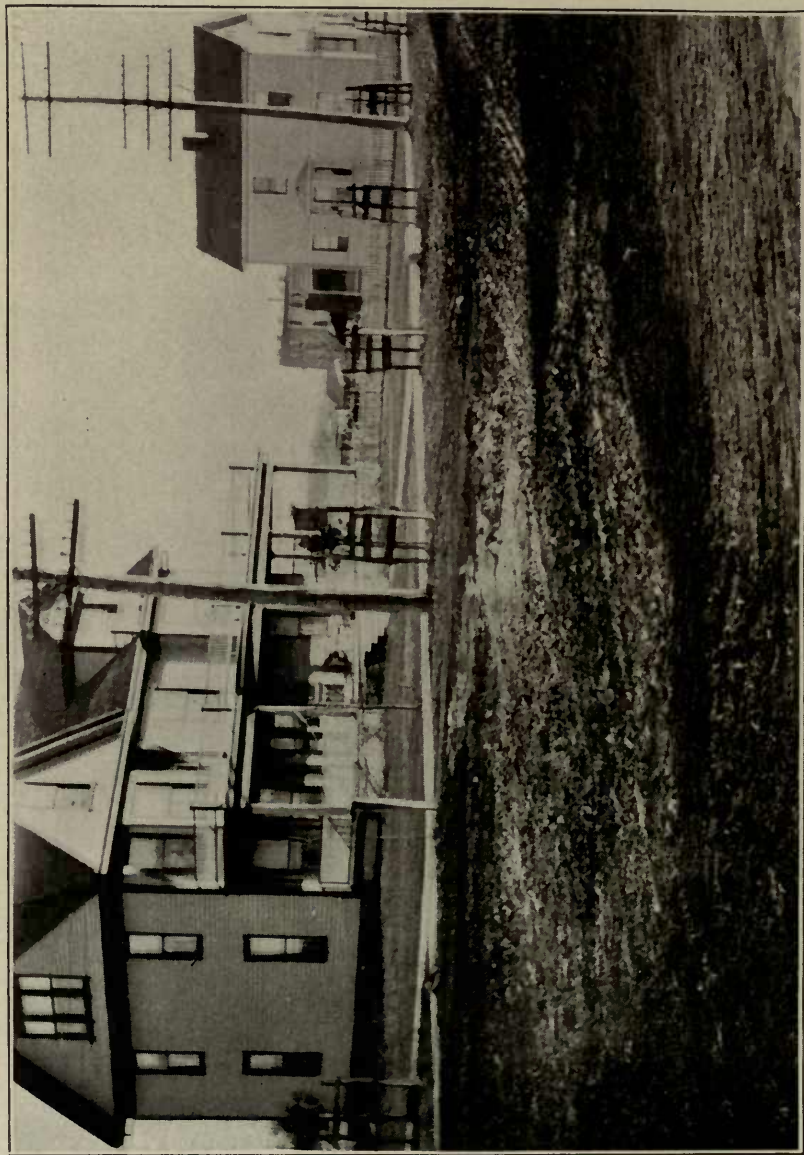
Stone and gravel occur very widely distributed over the State, and in most places it is a question of selecting that which is most suitable. In the northern portion of the State, where stone is scarce, there is an abundance of clay which might be burned in the same manner that gumbo is burned for ballasting the railroads. The method and cost of manufacturing this are discussed in another chapter. (See chapter II.)

It would require a volume to discuss in detail the materials available in each county for highways. Most counties, however,

are supplied with a variety of materials, some of which are better than others. Many of the stones available should be tested to determine their value as paving materials, and in the absence of stone the clays should be examined to ascertain their value for the manufacture of ballast.

The best stone is none too good for a pavement. Never use the waste from a quarry in case it consists of stone which has been rejected for building purposes on account of its softness. Wherever possible, use trap rock. If this is not available, granite, dolomite, limestone and flint in the order given. Flint alone cannot be used to advantage, except when mixed with limestone or when very finely crushed, as in the case of the chat from the Joplin mills. When it constitutes a part of a gravel bank, of which clay is the matrix, it is very desirable.





AN UNIMPROVED PORTION OF A PROMINENT STREET IN A MISSOURI CITY.

Typical for many of the smaller cities in the State.

CHAPTER VII.

PRESENT CONDITION OF RURAL HIGHWAYS AND CITY STREETS.

For the purpose of securing information covering the condition of the highways in this State, the following circular was sent to all rural mail carriers in the State, a list of whom was furnished the Bureau by the Fourth Assistant Postmaster-General. One thousand eight hundred and forty-nine (1,849) of these circulars were sent out. Out of this number sent out 1,654 replies were received, being nearly ninety per cent:

Number of route.....County
Location of route, from via to
Length Miles.
Is road earth, gravel, rock, chat, or burned clay and miles of each?
Condition of each kind of road in
 Winter
 Spring
 Summer
 Fall
Has condition of your route this past winter prevented general use of the roads, 1st, by loaded wagons; 2nd, by unloaded wagons (Do not include obstructions by snowdrifts)?
Has it been impassable, with mail wagon, except for snow drifts?.....
State about the number of days impassable.....
Have you been unable, except for snow drifts, to deliver the mail on your route, because of the condition of road?.....
What is the usual time of year that work is done on these roads?.....
What is the general nature of this work? Over what sections are road graders used?
Has any section of this road been dragged with a log or plank drag; if so, for what distance?
When was it first dragged?.....
About how many times do you estimate it has been dragged up to the present time?
By whom is dragging done? Give below the names and addresses of persons dragging the road
What has been the effect of dragging? What is the kind of soil on road, where dragged?
Are there any concrete or pipe culverts? State number.....
How many bridges and how many culverts on your route?.....
How many streams do you ford? How many are impassable at certain seasons of the year? Where are they located?
Is wood used for culverts and bridges?.....
Are there any vitrified clay pipe, or iron pipe culverts? State how many.....
Do the pipe culverts have protecting masonry end walls?.....

Give location and names of factories making drain tile, sewer pipe, paving brick and gumbo in or near the city where you live.....
 Give location and names of owners of quarries operated along or near your route.....

 Is the route which you travel level or hilly?.....
 How many and what are the heights of the hills?.....
 What is the average width of the improved part of the road?.....
 What is the weight of the maximum load drawn by two horses over the first six miles of your route?.....
 About what percentage of the wagons traveling over your route have broad tired wheels?

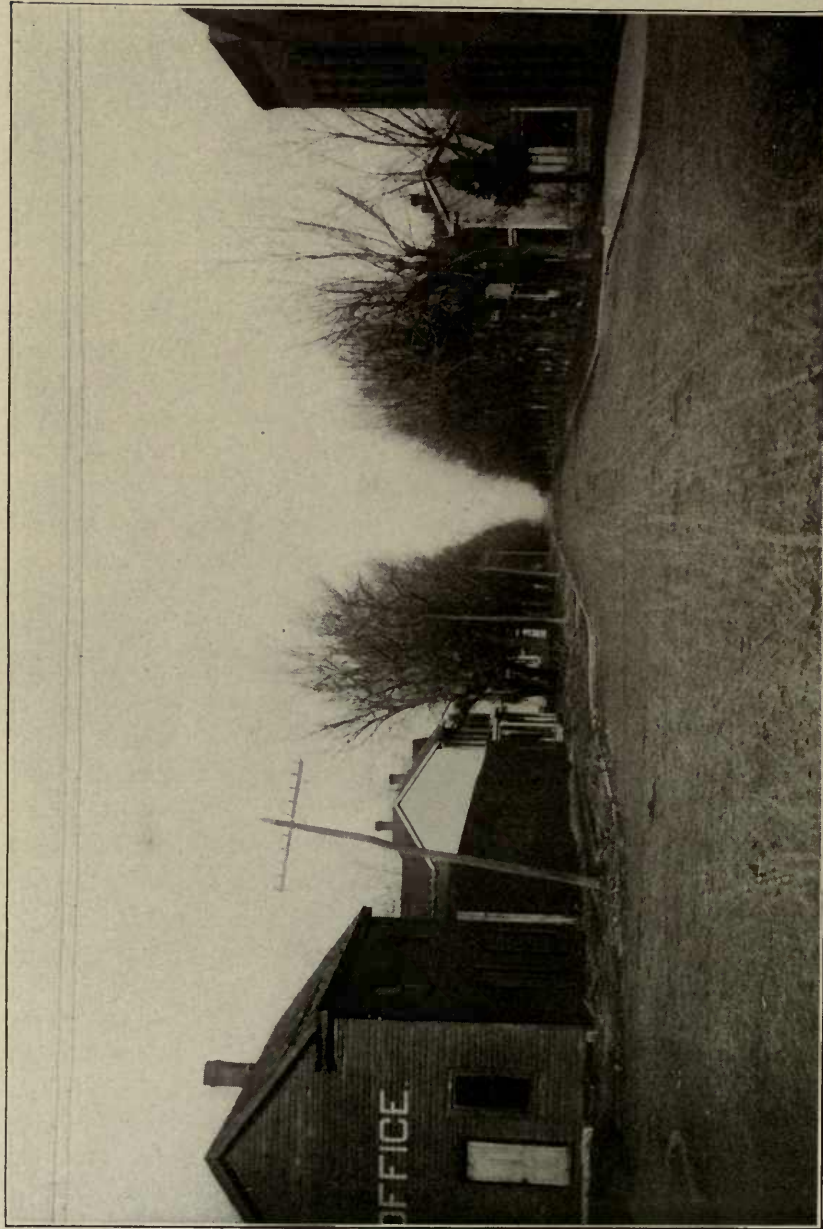
Table No. 1, which follows this chapter, has been compiled from these returns and is a fair representation of the condition of the main traveled highways of the State.

Circulars were sent to all towns and cities having a population of over 400, with a view to ascertaining the progress which had been made in street paving. In all 309 circulars were sent out, from which 129 replies were received. Of this number of replies, 84 reported nothing in the line of paving; 17 reported having used gravel on a portion of the streets; the remainder had used macadam, brick or some other material. Most cities report the construction of granolithic or brick sidewalks.

Outside of St. Louis, Kansas City, St. Joseph, Joplin, Moberly, Jefferson City, Boonville, Chillicothe, Mexico and Springfield (among those from which returns were received) there has been very little systematic work on the highways. A few of the smaller cities have constructed brick pavements around the public square and built gravel or macadam pavements on the streets having the most travel.

BRICK PAVEMENTS.

Three blocks of vitrified brick pavements, on a 4-inch concrete foundation, were built in Slater in 1905; cost \$1.74 per square yard. Concrete curbing, 25½ cents per lineal foot. Vitrified brick pavements in St. Louis, laid on a 6-inch concrete foundation, cost from \$1.70 to \$1.80 per square yard. Vitrified brick pavement laid in Richmond, in 1902, cost \$1.89 per square yard, including concrete foundation. Vitrified brick pavements laid on a 4-inch sand foundation, in Moberly, in 1906, cost \$1.08 per square yard. Other brick pavements have cost as high as \$1.32 per square yard. Vitrified brick pavements laid on a 6-inch sand foundation, in Moberly, have cost \$1.18 to \$1.23 per square yard. Concrete curbing costs 27 cents per lineal foot. Vitrified brick pavement on a 4-inch concrete foundation, in Chillicothe, cost \$1.70 per square yard; concrete curbing, 28 cents per lineal foot. Vitrified brick



MACADAM PAVEMENT, LOCUST STREET, CHILLICOTHE, MO.

pavements on a 6-inch concrete foundation, in Jefferson City, have cost \$1.82 and \$1.84 per square yard; concrete curbing, from 45 to 50 cents per lineal foot. Vitrified brick pavement on a 3½-inch concrete foundation, laid in 1906, cost \$1.22 per square yard. Vitrified brick pavement, in Mexico, cost \$1.44 per square yard. These pavements are reported, almost without exception, as being good. The only complaint is that they are noisy.

MACADAM AND TELFORD PAVEMENTS.

Four blocks of telford limestone pavement, constructed in 1894 and 1896, in Milan, cost, including curb and gutters, \$7.00 per square or about 64 cents per square yard. This pavement was built 9 inches thick and is reported as being in good condition. The sale of the dirt which accumulates on the street pays for cleaning. Webster Groves has twenty-five miles of limestone macadam. It is built the full width of the street—60 feet—and is eleven inches thick. The foundation course of 7 inches is rip rap, making the pavement a sort of a telford.

These pavements cost 66½ cents per square yard and are reported to be in good condition. These pavements wear about three years without the necessity of repair, after which they cost about \$40 a mile, annually.

Clinton reports about four blocks of limestone macadam, which has been in about twenty years; has never been repaired, and is in bad condition.

The principal streets of Hermann have been macadamized their entire width, and have curbs and gutters. Crushed limestone and gravel are used, the former being spread 8 to 10 inches deep and covered with a thin layer of gravel and clay. This is reported as making "a fine and durable street."

The main street of Kingston is macadamized with limestone. The pavement consists of 4 inches of coarse broken stone and 2 inches of finely crushed stone for surfacing, costing about 31 cents per square yard. Mr. C. W. M. Love, city clerk, says "Establish grade and build with macadam, 6 inches coarse and 4 inches fine. Build as much as possible each year. If only one inch can be built each year, build in that way. Build some every year." This is good advice.

In St. Ferdinand there are two miles of limestone macadam, which has not been repaired for years, except at crossings. It is reported to be in good condition. This pavement was built by lay-

ing a foundation of ten inches of rip rap and spreading over the surface five inches of crushed limestone. The water is drained by means of gutters and pipe culverts under crossings.

In Liberal one block has been improved by laying a 6-inch foundation of broken stone covered with three inches of chat. The remaining streets are improved with a grader pulled by a traction engine. Sidewalks consist of brick, laid flat on a foundation of 4 inches of gravel. Between the brick and the foundation there is a two-inch layer of sand.

Golden City has about a mile of pavement built out of crushed rock (chat) about 4 inches thick.

The Joplin special road district has about one hundred miles of road which has been paved with broken stone and chat. These pavements are excellent, as shown by the accompanying illustrations.

GRAVELED STREETS.

Many of the cities in the State have improved their streets by covering the surface with gravel, and where there is no opportunity of securing a better pavement, this should be encouraged.

Chamois has a mile of streets improved with gravel. These streets are now improved by laying a six-inch course of boulders, covering them with 8 inches of gravel. This costs about \$1.00 per square yard. Mr. S. W. Laughlin says that he believes creek gravel to be much more durable than crushed rock. This city is constructing granitoid and brick walks, now having about 600 feet of the former and 1,000 feet of the latter.

Potosi has about $3\frac{1}{2}$ miles of streets improved with gravel. They consist of 6 inches of broken stone from the mine dumps, covered with a layer of clay and then a 4-inch layer of gravel. Mr. James A. Shields, Jr., city clerk, says, "As near as I can find out from former city officials, the cost of making our streets has been about \$800 per mile, and can be re-graveled for about \$400 per mile. After a street is once paved, it will last about two years without repairs, after which a few loads of gravel on the worn places will keep it in good condition for from 6 to 8 years, at an annual cost of not to exceed \$75.00." The drainage in this city is good, which, in part, at least, accounts for the durability of the pavements.

Two blocks in Osceola have been improved with gravel, obtained from the Osage river. The gravel is laid 6 inches in thickness, and the streets thus improved are reported to be in excellent condition, and have thus far required no repairs.





COUNTY ROAD BETWEEN LINN CREEK AND LEBANON, MO.
(Photo by Dr. E. M. Shepard.)

Nearly all the streets of Tipton, about four miles, have been covered with gravel from nearby streams. The gravel is spread from 8 to 12 inches thick over a width of 35 feet of the road. The gravel costs 45 cents per ton delivered. All streets leading into the country are also graveled for a distance of two to four miles, the cost being paid in part by subscription and in part by the county court.

In Sullivan gravel is the principal material used. It costs 45 cents per cubic yard after grading is done. It is laid from 12 to 18 inches thick. One street was improved with chat from the Joplin mines, and it is reported to wear fully twice as long as creek gravel. The chat used cost 95 cents per cubic yard, while creek gravel costs 45 cents per cubic yard.

At Dadeville there is a mile of graveled streets, built out of 2 inches of broken stone covered with 4 inches of gravel. The cost was 6 cents per square yard.

At Lutesville there is about one-fourth mile of graveled streets in good condition. Mr. W. T. Dickey says that the streets "should have a stone foundation. The gravel is too light and gets soft in wet weather." The graveled streets cost about 25 cents per square yard, and curbing 1 cent per lineal foot.

There are many other cities in which gravel has been used, but those referred to above give an excellent idea of the manner and cost of constructing this kind of pavement in the cities of this State.

SIDEWALKS.

In most towns and cities in the State the wooden sidewalk is a thing of the past. When one considers its serviceability and durability it is more costly than either the granitoid or brick walk. Well seasoned two-inch plank are the only boards suitable for walks, and when one considers the cost of lumber, he will select either one-inch lumber, granitoid or brick. The board walk will cost about 3 cents a square foot and the granitoid 12 to 14 cents. The latter, if properly constructed, will last indefinitely and the former four or five years. The granitoid is safe, when free from ice; the wood, when old, is dangerous.

In the smaller cities of the State, the almost uniform practice is to make the walks ten feet wide on the business streets and four feet wide on the residence streets.

In LaBelle the granitoid walks are built 5 inches thick. The foundation course of 4 inches consists of one part cement and seven

parts gravel or crushed rock. The surface consists of one inch of mortar, composed of one part of cement and two parts of finely crushed stone. At DeWitt burnt clay ballast is used for the foundation, and also in place of gravel or crushed stone for making the granitoid. This is interesting, in so much as it shows the usefulness of burnt clay ballast (gumbo) where gravel and stone are scarce. (See chapter II.)

In Breckenridge, where six miles of granitoid walks have been built since 1902, it has been observed that the walks are more substantial where excavations for the same are made and filled with crushed stone and screenings in the fall and allowed to settle during the winter and spring. This makes a more substantial foundation than can be made by tamping. The specifications under which the granitoid walks in Breckenridge have been laid are sufficiently good to warrant publishing in this place. They were furnished by the city clerk, Mr. H. G. Motsingers, and are as follows:

Excavate from grade of street to a depth of 12 inches. Upon this excavation or subgrade there shall be placed a layer of broken stone which, after being thoroughly tamped, shall be 8 inches thick, and which formation shall be properly prepared before concrete hereinafter mentioned is placed thereon.

Upon this foundation, aforesaid, there shall be placed a concrete base $3\frac{1}{2}$ inches in thickness composed of the best American Portland cement, clean, sharp, coarse sand and clean hard limestone screenings or clean crushed stone (no piece or fragment thereof to exceed $1\frac{1}{2}$ inches in its largest dimensions) and all mixed together in the following proportions.

One part cement.

Two parts sand.

Four parts screenings or clean crushed stone.

The cement and sand in the above proportions shall be thoroughly mixed dry and then screenings or stone to be added and mixed, then sufficient clean water shall be added to properly wet it and then the entire mass thoroughly and uniformly mixed.

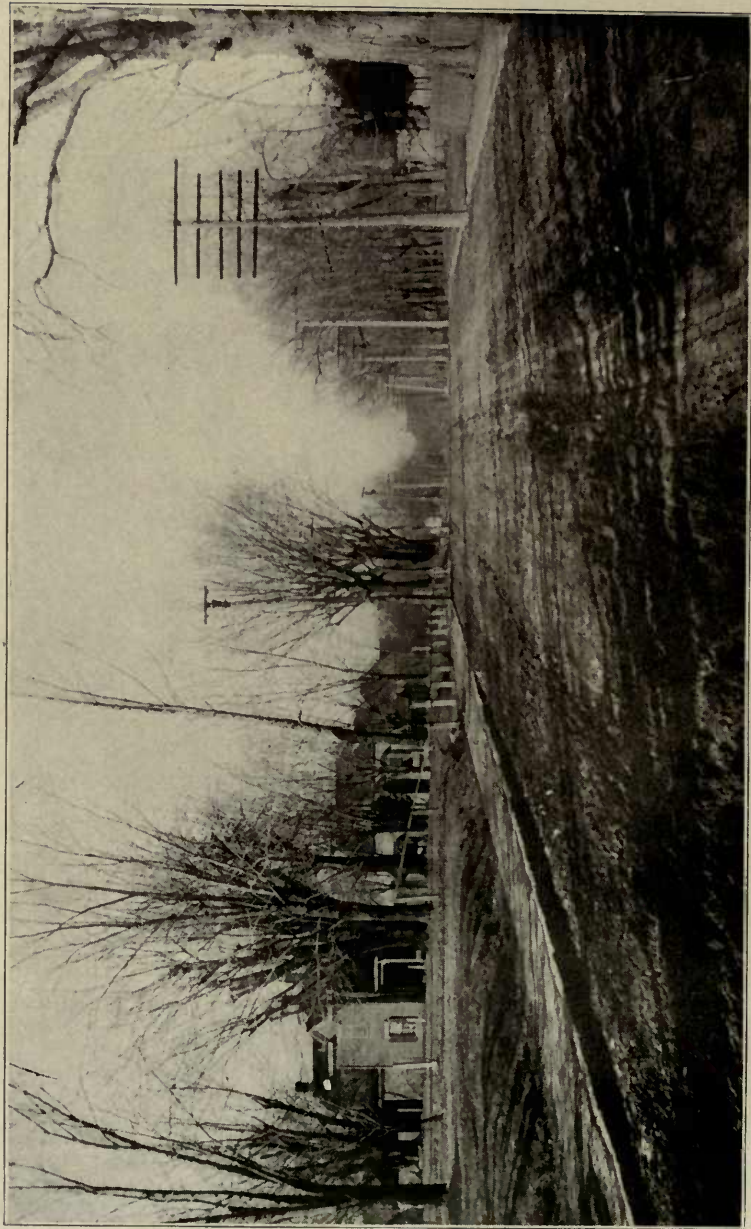
Upon the base as above described shall be laid a wearing surface not less than $\frac{1}{2}$ inch in thickness composed of, 2 parts best American Portland cement; 2 parts Joplin flint, and 1 part good Grand river sand.

All thoroughly mixed dry—then intelligently wetted and skillfully spread. This finishing course must be spread on the base and floated, while the base is still soft and adhesive after which the surface shall be smoothed and compacted and thoroughly and skillfully troweled before cement is too hard for finishing.

These walks have cost about \$1.25 per square yard. It is thought that in order to prevent slipperyiness the surface should be broomed and not troweled. It might also be a wise precaution to have the walk covered with a wet canvas from twenty-four to thirty-six hours, which will protect the surface from injury by too rapid drying.

In Hamilton granitoid walks are laid on a cinder foundation





MACADAM PAVEMENT, BUILT IN 1895, EAST MAIN STREET, RICHMOND, MO.

ten inches deep. The concrete base consists of three parts of Joplin flint, one part sand and one part Portland cement. The surface is made out of three parts fine flint and two parts Portland cement.

In the above very little is said about the construction of brick sidewalks. These, when properly constructed out of vitrified brick, are equally as desirable as granitoid. However, on a clay or loam subsoil, the brick should be laid on a concrete foundation, and the joints should be filled with cement grouting, as in the case of brick pavements discussed in a previous chapter.

TABLE NO. 1.

TABLE SHOWING THE CONDITION OF THE ROADS TRAVELED BY THE RURAL FREE DELIVERY CARRIERS OF MISSOURI—1906.

County.	No. of routes reported.	Total mileage of roads reported.	No. of routes impassable with mail wagon.	Av. No. days impassable with mail wagon.	No. of routes impassable except on foot....	Av. No. days impassable except on foot....	No. miles road dragged over all routes..	No. of pipe culverts...	No. of wooden culverts	Total number culverts	Total number bridges.	Total number fords...	No. fords that are impassable at times....	Av. load hauled over first six miles of route	Av. percentage broad-tired wagons in use..
Adair.....	13	312.	13	56.4	11	4.25	108.5	20	548	568	148	14	5	2600	1.6
Andrew.....	19	465.4	18	37.6	13	5.1	110.	186	548	734	285	14	6	2200	1.5
Atchison.....	18	438.12	8	16.7	3	30.0	122.5	23	254	277	224	2	1	2341	.6
Audrain.....	26	610.4	26	53.1	20	6.	148.	8	1481	1489	158	12	9	2604	.74
Barry.....	12	299.1	1	6.	2	1.	7.	12	87	99	1	27	15	2108	.16
Barton.....	16	419.9	7	15.	1	3.	30.5	21	522	543	111	41	22	2866	1.25
Bates.....	31	771.6	27	18.4	12	3.75	218.5	69	1233	1302	122	92	43	2448	.57
Benton.....	8	201.75	5	50.	1	2.	13.25	17	147	164	11	26	8	2437	.12
Bollinger.....	1	21.	0	0	0	0	0	0	0	0	5	10	2	2000	5.
Boone.....	25	566.25	24	42.4	19	9.1	187.	18	1109	1127	123	31	4	3048	.85
Buchanan.....	23	560.4	18	21.1	9	7.6	145.	290	237	533	311	36	13	2595	2.8
Butler.....	2	46.1	1	30.	0	0	2.	3	57	60	8	5	2	2250	3.
Caldwell.....	25	581.5	25	40.8	21	17.	193.25	150	733	883	180	29	14	2400	2.4
Callaway.....	32	707.12	29	64.1	17	7.4	177.75	53	1033	1136	91	108	44	2665	1.3
Cape Girardeau.....	13	301.	4	9.7	2	2.	15.	21	173	194	88	71	45	2175	5.24
Carroll.....	34	828.	34	43.6	30	11.3	256.5	47	1259	1306	468	18	2	2502	4.
Carter.....	1	21.75	0	0	0	0	0	0	7	7	1	10	0	2000	.....
Cass.....	31	688.75	29	28.1	8	1.	178.	98	1148	1246	157	39	21	2727	2.
Cedar.....	8	189.25	4	56.	1	?	16.4	2	197	199	14	18	5	2500	0.62
Charlton.....	26	604.4	22	57.1	21	6.	110.	70	890	960	195	8	3	2617	1.8
Christlan.....	7	185.5	0	0	0	0	5.	0	70	70	4	6	2	3271	.14
Clark.....	15	37.4	15	46.	12	5.6	171.5	33	655	688	368	5	1	2896	1.13
Clay.....	19	435.12	19	37.5	9	.....	206.5	73	618	691	152	38	16	2737	1.11
Clinton.....	25	598.25	23	46.3	17	9.5	288.5	155	925	1080	255	33	6	2456	2.56
Cole.....	11	231.37	7	15.2	3	5.	0	88	26	114	34	32	12	2200	1.37
Cooper.....	20	864.25	17	32.1	7	4.	138.	98	221	1019	49	58	26	2094	1.55
Crawford.....	2	51.	1	90.	0	0	7.	3	0	3	2	5	2	1750	2.
Dade.....	15	355.5	8	17.5	4	6.6	9.	6	250	266	14	49	26	2325	1.73
Dallas.....	7	160.5	3	23.6	1	.....	3.5	0	84	84	7	18	5	1871	0
Davless.....	20	482.8	20	40.3	16	8.3	288.5	30	807	837	200	31	13	2250	1.7
DeKalb.....	25	584.8	22	28.5	12	3.	224.	85	1562	1647	316	13	9	2484	1.6
Dent.....	1	31.25	0	?	0	.....	.5	0	0	0	0	2	2	1500	0.
Dunklin.....	3	66.75	1	60.	1	3.	6.	0	94	94	23	0	0	2206	10.6

TABLE NO. 1—Continued.

County.	No. of routes reported.	Total mileage of roads reported.	No. of routes impassable with mail wagon.	Av. No. days impassable with mail wagon.	No. of routes impassable except on foot.	Av. No. days impassable except on foot.	No. of routes impassable over all routes.	No. miles road dragged over all routes.	No. of pipe culverts.	No. of wooden culverts.	Total number culverts.	Total No. bridges.	Total No. fords.	No. fords that are impassable at times.	Av. load hauled over first six miles of route.	Av. percentage broad-tired wagons in use.
Franklin.....	13	310.6	9 29.	5 4.	21.	163	104	267	44	34	8	2346	1.9			
Gasconade.....	1	25.	1 5.	0 0	0	16	21	37	2	3	0	3000	5.			
Gentry.....	25	591.7	24 33.3	6 3.	270.75	88	1317	1405	233	15	7	2674	1.4			
Green.....	33	778.	10 5.2	5 2.6	0.75	35	368	405	63	85	38	2283	.9			
Grundy.....	16	394.6	15 38.7	10 4.6	223.	114	687	801	202	1	0	2500	.1			
Harrison.....	26	606.6	22 39.6	14 3.	303.5	23	1066	1089	336	17	4	2520	1.2			
Henry.....	37	940.	28 34.	19 3.	253.	140	1541	1681	193	70	32	3027	1.			
Hickory.....	2	45.	1 25.	0 0	11.5	0	12	12	2	4	2	2000	0			
Holt.....	19	494.75	18 17.7	9 2.6	188.25	4	162	166	225	2	1	2233	1.4			
Howard.....	10	239.75	10 32.4	9 10.5	117.5	6	162	168	101	7	1	3200	.7			
Howell.....	9	212.9	3 2.5	2 2.5	1.5	0	61	61	7	15	7	2412	1.4			
Jackson.....	38	915.	32 28.1	16 2.8	68.	266	839	1105	288	36	18	2940	1.77			
Jasper.....	30	731.5	4 16.2	1 2.	2.	73	474	547	77	56	36	3982	3.0			
Jefferson.....	7	170.1	2 30.	0 0	0	21	68	89	54	19	9	2216	1.0			
Johnson.....	38	877.12	33 47.5	21 4.	328.3	106	1640	1746	281	41	29	2917	1.6			
Knox.....	14	333.6	14 32.7	9 2.	125.25	5	737	742	93	3	2	2254	0			
Laclede.....	8	169.5	2 15.	1 2	11.5	6	117	123	8	9	8	2330	1.1			
Lafayette.....	28	675.9	26 32.4	20 5.6	346.	25	961	986	667	24	10	2754	1.			
Lawrence.....	30	935.8	2 9.	1 1.	13.	28	167	195	12	77	45	2800	.44			
Lewis.....	21	508.25	20 66.	15 8.8	80.	14	832	846	248	17	13	2425	1.			
Lincoln.....	23	504.0	23 43.6	15 5.	52.25	38	600	638	70	72	32	2718	1.6			
Linn.....	36	868.85	35 51.5	29 9.9	360.25	140	1944	2080	589	12	6	2147	.87			
Livingston.....	18	416.0	18 59.	15 5.	151.5	116	552	668	299	9	2	2200	1.6			
McDonald.....	9	209.85	2 18.5	3 2.	0.25	0	95	95	2	13	4	2300	.33			
Macon.....	30	701.75	30 44.4	24 8.43	19.5	48	1926	1974	229	10	3	2416	1.2			
Madison.....	1	21.5	1 10.0	1 2	0	0	20	20	0	3	1	1200	2.			
Marion.....	10	241.6	8 20.3	4 4.5	37.	17	429	446	79	11	9	2490	1.3			
Mercer.....	12	287.85	11 19.5	10 6.75	164.75	47	347	394	92	17	5	2250	1.6			
Miller.....	2	47.5	1 60.	0 0	1.	9	35	44	4	5	0	2750	2.5			
Mississippi.....	3	57.85	0 0	0 0	0	6	20	28	5	0	0	4000	50.			
Moniteau.....	18	467.85	16 38.	9 7.	33.5	99	375	474	64	66	40	2360	1.1			
Monroe.....	18	448.85	18 62.4	13 4.3	119.	23	1012	1035	74	36	23	2361	.68			
Montgomery.....	18	384.85	16 43.6	7 2.6	80.5	30	949	979	62	28	15	2133	1.8			
Morgan.....	4	92.0	3 27.	2 2	5.	0	68	68	18	20	12	2500	3.			
Newton.....	17	411.25	8 4.6	1 1.	0	2	178	180	9	38	16	2406	.26			
Nodaway.....	41	395.25	39 27.2	27 10.6	267.5	182	1832	1914	857	1	0	2452	2.2			
Oregon.....	2	52.6	2 5.5	2 5.5	0	0	0	0	0	0	5....	1500	40.			

TABLE 1—Continued.

County.	No. of routes reported.	Total mileage of roads reported.	No. of routes impassable with mail wagon.	Av. No. days impassable with mail wagon.	No. of routes impassable except on foot.	Av. No. days impassable except on foot.	No. miles road dragged over all routes.	No. of pipe culverts.	No. of wooden culverts.	Total number culverts.	Total No. bridges.	Total No. fords.	No. fords that are impassable at times.	Av. load hauled over first six miles of route.	Av. percentage broad-tired wagons in use.
Osage.....	1	20.25	0	0	0	0	0	0	4	4	1	1	0	Lbs. 1500	.....
Perry.....	5	117.36	2	3.5	2	3.5	7.00	36	39	75	13	20	18	2700	1.8
Pettis.....	22	515.5	22	63.1	18	9.9	91.	59	841	900	123	38	20	2988	2.3
Phelps.....	2	46.36	0	0	0	0	0	0	16	16	20	9	0	2000	0
Pike.....	31	713.0	19	48.7	6	2.3	52.75	55	536	591	307	132	78	2647	3.6
Platte.....	26	611.35	17	36.7	12	6.	197.5	100	637	737	216	80	25	2520	1.83
Polk.....	27	456.12	8	18.3	0	0	3.25	12	489	501	39	114	37	2104	1.5
Pulaski.....	2	48.25	0	0	0	0	0	1	1	2	4	8	0	1350	0
Putnam.....	12	299.5	12	24.8	8	5.5	129.5	10	342	352	150	12	8	2333	.8
Ralls.....	10	222.75	10	46.2	6	2.	22.5	3	439	442	54	20	14	2311	.75
Randolph.....	27	659.25	26	74.2	20	4.8	245.5	53	1457	1510	183	40	24	2722	.54
Ray.....	21	506.85	20	33.8	11	5.8	152.5	52	491	543	100	38	12	2400	7.
Ripley.....	1	23.5	0	1	0	0	72.	0	15	15	0	6	3	2000	2.
St. Charles.....	19	460.3	18	36.6	10	11.8	93.92	72	334	406	156	35	14	2222	2.8
St. Clair.....	10	238.	7	17.3	6	2.	38.	1	218	219	64	30	22	2260	1.3
St. Francois.....	2	46.6	1	12.0	1	2.	4.	36	45	81	1	6	1	3500	0
St. Louis.....	27	620.37	21	35.7	14	30.	1.	373	239	611	244	29	24	2684	7.6
Saline.....	27	545.12	25	57.12	16	4.8	22.7	83	796	879	328	15	4	2660	1.2
Schuyler.....	16	371.5	15	41.	12	6.5	161.5	41	604	645	221	1	0	2533	1.08
Scotland.....	11	270.75	11	26.1	8	3.	125.	7	477	484	84	6	2	2045	1.5
Scott.....	4	91.37	0	0	0	0	23.5	7	31	38	32	11	1	2250	52.
Shelby.....	26	615.6	25	51.3	20	5.6	185.75	4	1439	1443	139	29	8	2680	.14
Stoddard.....	7	153.05	1	12.	1	5.	1.25	5	179	184	150	10	2	2286	18.5
Stone.....	3	68.25	0	0	0	0	0	1	4	5	2	6	2	2000	0
Sullivan.....	30	677.25	25	38.2	20	4.55	274.5	83	1619	1702	424	15	10	2140	2.24
Vernon.....	19	452.75	14	29.7	3	?	104.0	13	821	834	84	27	11	3011	1.5
Warren.....	11	273.25	10	43.5	5	11.	33.5	108	86	194	58	30	26	2300	0
Washington.....	1	20.5	1	21.0	0	0	0	0	3	3	0	6	6	900	0
Webster.....	18	409.85	8	10.6	5	1.5	4.87	1	222	223	6	32	14	2166	1.3
Worth.....	13	309.37	10	22.8	5	3.5	215.	8	727	735	182	3	0	2066	.85
Wright.....	12	266.56	4	6.5	3	1.	1.25	0	63	63	14	33	20	2636	.27

TABLE NO. 2.*

Mileage and expenditures in 1904.—Public roads of Missouri.

County.	Miles of public roads.				Expenditures in money and labor.			
	Esti- mated total.	Sur- faced with grav- el. ^a	Sur- faced with stone ^a	Road levy— rate per \$100.	Amount expended in cash. ^b	Labor tax.		
						Men sub- ject to tax.	Days labor per man.	Value of labor at \$1 per day.
					Dollars.			Dollars.
Adair.....	900			c25	15,000 00	1,600	3	4,800 00
Andrew.....	725			30	22,000 00	1,750	2	3,500 00
Atchison.....	900			28	27,000 00	1,907	3	5,721 00
Audrain.....	1,170			20	14,000 00	1,360	3	4,080 00
Barry.....	1,350			15	6,000 00	2,500	4	10,000 00
Barton.....	1,000	3		15	3,402 00	3,500	2	7,000 00
Bates.....	1,580		2	15	8,000 00	4,000	2	8,000 00
Benton.....	1,418			10	4,162 58	1,800	4	7,200 00
Bollinger.....	1,125			15	3,181 79	2,073	4	8,292 00
Boone.....	1,381	44	1	10	6,481 11	2,940	4	11,760 00
Buchanan.....	1,050		11	15	52,000 00	2,355	3	7,065 00
Butler.....	1,242		½	15	8,500 00	1,900	3	5,700 00
Caldwell.....	855			15	7,500 00	3,000	2	6,000 00
Callaway.....	1,440	20		25	13,700 00	3,988	3	11,964 00
Camden.....	1,240			15	1,600 00	1,500	4	6,000 00
Cape Girardeau	1,010	75		20	8,803 56	2,524	4	10,096 00
Carroll.....	1,215			(d)	15,610 18	2,878	2	5,756 00
Carter.....	873			5	1,200 00	1,050	3	3,150 00
Cass.....	1,323			15	15,000 00	3,000	1	3,000 00
Cedar.....	630			10	3,700 00	2,636	3	7,908 00
Chariton.....	1,211			15	11,553 00	2,611	3	7,533 00
Christlan.....	900			15	4,500 00	2,000	4	8,000 00
Clark.....	900			20	10,000 00	1,800	3	5,400 00
Clay.....	720			15	6,341 92	2,000	2	4,000 00
Clinton.....	900			10	7,000 00	1,700	3	5,100 00
Cole.....	900	e80	e120	20	3,000 00	1,000	4	4,000 00
Cooper.....	852			10	12,927 45	2,460	3	7,380 00
Crawford.....	1,283			13	5,102 74	1,568	3	4,704 00
Dade.....	630	25		20	7,000 00	3,600	3	10,800 00
Dallas.....	625	75		10	2,100 00	1,800	4	7,200 00
Davless.....	1,000		1½	15	16,683 84	2,800	2	5,600 00
DeKalb.....	704			15	8,000 00	2,500	2	5,000 00
Dent.....	630	10		10	3,900 00	1,400	3	4,200 00
Douglas.....	1,850			10	2,000 00	2,300	4	9,200 00
Dunklin.....	900			20	3,500 00	1,750	4	7,000 00
Franklin.....	1,553	80	35	20	12,968 00	3,242	4	12,968 00
Gasconade.....	900	10	48	25	7,953 10	1,755	4	7,020 00
Gentry.....	743			15	6,500 00	3,000	4	12,000 00
Greene.....	1,148	10		20	39,448 35	4,141	3	12,423 00
Grundy.....	743			15	12,000 00	1,800	4	7,200 00
Harrison.....	1,260			15	12,750 00	1,850	2	3,700 00
Henry.....	1,300		1¼	15	14,000 00	2,900	3	8,700 00
Hickory.....	697			8	1,600 00	1,300	3	3,900 00
Holt.....	800			10	6,090 00	1,981	3	5,943 00
Howard.....	630			10	6,500 00	2,000	3	6,000 00
Howell.....	808			15	4,000 00	2,000	4	8,000 00
Iron.....	450			10	1,458 56	800	2	1,600 00
Jackson.....	1,000		193	15	223,282 11	3,000	3	9,000 00
Jasper.....	900	g365		10	60,971 36	1,695	2½	4,237 50
Jefferson.....	1,000		100	15	15,000 00	3,500	3	10,500 00
Johnson.....	1,455		3	15	16,500 00	2,650	3	7,950 00
Knox.....	756			20	8,061 86	1,500	2	3,000 00
Laclede.....	1,083	1		10	3,052 55	2,130	4	8,520 00
Lafayette.....	1,034			5	9,059 00	3,292	4	13,168 00
Lawrence.....	1,000	100		20	14,220 00	6,000	4	24,000 00
Lewis.....	863	25		20	7,037 00	1,387	3	4,161 00
Lincoln.....	1,061			15	7,000 00	2,479	3	7,497 00
Linn.....	954			15	10,843 85	1,355	2	2,710 00
Livingston.....	900			(d)	17,005 93	2,664	2	5,328 00

^aWhere figures are not given in these columns, no mileage has been reported.

^bIncludes amounts expended from dramshop funds.

^cTen cents for county fund and 15 cents for district fund.

^dRate varies in different townships.

^eJudging from the amount expended, this seems to be an excessive mileage, but the county clerk of this county, in answer to inquiry, replied that he considered the information correct.

^fIncludes \$194,911.52 derived from dramshop fund.

^gThese roads are constructed of "chats," a by-product from zinc and lead mines.

*This table is copied from circular No. 72, Office of Public Roads, U. S. Department of Agriculture, by M. O. Eldridge. The reader is referred to that circular for fuller information and explanation as to the manner of arriving at the figures given.

Mileage and expenditures in 1901—Continued.

County.	Miles of public roads.			Expenditures in money and labor.					
	Esti- mated total.	Sur- faced with grav- el.	Sur- faced with stone.	Road levy— rate per \$100.	Amount expended in cash.	Labor tax.			Total ex- penditures in cash and labor.
						Men sub- ject to tax.	Days' labor per man.	Value of labor at \$1 per day.	
					Dollars.			Dollars.	Dollars.
McDonald'.....	670	1	.....	15	1,800 00	1,300	4	5,200 00	7,000 00
Macon.....	1,440		.....	15	15,000 00	3,000	3	9,000 00	24,000 00
Madison.....	854	5	.....	20	3,500 00	1,500	3	4,500 00	8,000 00
Marles.....	900		.....	15	2,625 00	1,450	4	5,800 00	8,425 00
Marion.....	740	124	.....	25	17,000 00	4,800	2	9,600 00	26,600 00
Mercer.....	742		.....	15	7,230 92	2,145	3	6,435 00	13,665 92
Miller.....	1,037	50	25	15	7,500 00	2,500	3	7,500 00	15,000 00
Mississippi.....	700		.....	15	3,400 00	1,680	3	5,040 00	8,440 00
Moniteau.....	800	12	4	20	6,485 00	3,050	3	9,150 00	15,635 00
Monroe.....	1,150	10	1	(a)	4,000 00	3,000	3	9,000 00	13,000 00
Montgomery.....	900	10	.....	15	10,506 27	1,939	3	5,817 00	16,323 27
Morgan.....	61,025		5	20	1,218 25	2,000	3	6,000 00	7,218 25
New Madrid.....	1,100		.....	20	6,750 00	1,100	4	4,400 00	11,150 00
Newton.....	775	30	½	20	13,000 00	4,000	3	12,000 00	25,000 00
Nodaway.....	1,500		.....	15	12,000 00	5,000	3	15,000 00	27,000 00
Oregon.....	775		.....	15	3,500 00	1,000	4	4,000 00	7,500 00
Osage.....	1,040	100	.....	25	17,532 85	1,975	3	5,925 00	23,457 85
Ozark.....	775		.....	10	1,200 00	1,600	4	6,400 00	7,600 00
Pemiscot.....	800		.....	(c)	7,600 00	1,200	4	4,800 00	12,400 00
Perry.....	600	100	5	12½	4,214 13	2,000	3	6,000 00	10,214 13
Pettis.....	1,188		20	15	30,542 98	2,144	3	6,432 00	36,974 98
Phelps.....	1,162	50	.....	20	6,288 99	2,551	3	7,653 00	13,921 99
Pike.....	1,050	78	.....	20	9,000 00	2,300	3	6,900 00	15,900 00
Platte.....	600		.....	20	10,000 00	1,500	2	3,000 00	13,000 00
Polk.....	1,075		.....	15	7,000 00	2,800	4	11,200 00	18,200 00
Pulaski.....	900		.....	10	1,650 00	1,200	4	4,800 00	6,450 00
Putnam.....	885		.....	15	2,500 00	1,500	2	3,000 00	5,500 00
Ralls.....	825	30	5	20	8,106 56	1,460	3	4,380 00	12,486 56
Randolph.....	840		1½	10	7,838 91	1,900	4	7,600 00	15,438 91
Ray.....	975		.....	20	15,000 00	3,066	4	12,264 00	27,264 00
Reynolds.....	625		.....	5	800 00	1,200	4	4,800 00	5,600 00
Ripley.....	1,080		.....	15	3,000 00	1,565	4	6,260 00	9,260 00
St. Charles.....	720	125	15	10	443,046 92	2,250	2	4,500 00	47,546 92
St. Clair.....	1,220		.....	15	5,800 00	3,000	3	9,000 00	14,800 00
Ste. Genevieve.....	520	20	.....	20	4,500 00	1,200	4	4,800 00	9,300 00
St. Francois.....	780	5	22	15	6,500 00	4,000	2	8,000 00	14,500 00
St. Louis.....	1,180	75	225	(e)	273,774 99	(f)	.....	.....	273,774 99
Saline.....	1,253		.....	15	12,800 32	3,481	3	10,443 00	23,243 32
Schuyler.....	475		.....	15	3,202 33	1,163	4	4,652 00	7,854 33
Scotland.....	775		.....	15	6,333 12	1,400	3	4,200 00	10,533 12
Scott.....	700	18	1½	15	11,842 31	2,062	3	6,186 00	18,028 31
Shannon.....	840	½	(a)	4	4,261 00	1,000	2	2,000 00	6,261 00
Shelby.....	705	5	.....	20	14,961 41	2,000	3	6,000 00	20,961 41
Stoddard.....	1,065		.....	15	6,473 56	3,806	4	15,224 00	21,697 56
Stone.....	450		.....	15	2,116 87	1,552	4	6,208 00	8,324 87
Sullivan.....	1,122		.....	15	9,000 00	3,300	3	9,900 00	18,900 00
Taney.....	540		.....	10	800 00	1,200	4	4,800 00	5,600 00
Texas.....	990	60	.....	10	3,200 00	1,800	4	7,200 00	10,400 00
Vernon.....	1,462		.....	25	15,000 00	4,000	3	12,000 00	27,000 00
Warren.....	700		.....	30	9,000 00	1,500	3	4,500 00	13,500 00
Washington.....	1,200	30	2	10	2,200 00	2,500	2	5,000 00	7,200 00
Wayne.....	1,232	10	.....	20	6,000 00	2,000	4	8,000 00	14,000 00
Webster.....	740		.....	10	9,363 00	2,334	4	9,336 00	18,699 00
Worth.....	346		.....	15	4,000 00	1,600	4	6,400 00	10,400 00
Wright.....	630		.....	10	11,048 76	2,098	4	8,392 00	19,440 76
Total.....	108,133	1,871½	861½	.....	1,570,801 29	256,542	.....	798,171 50	2,368,972 79

aRate varies in different townships.

bIncludes 60 miles of natural gravel roads.

cNo levy made; cash derived from dramshop fund.

dOf this amount, \$12,385.63 was received from dramshop funds.

eRate not reported.

fNumber of men subject to labor tax not reported.

gOf this amount, \$7,227.89 was received from dramshop fund.

CHAPTER VIII.

MISCELLANEOUS CONSIDERATIONS.

THE KIND OF PAVEMENT TO CONSTRUCT.

Every town, village or city, some time in its history, is confronted with the problem of selecting pavements for streets or public highways. It is sometimes difficult to determine that which is most suitable. It is seldom, if ever, possible to construct a pavement which will meet with universal approval.

A single kind of pavement should not be selected for all the streets of a city. The varying conditions, as regards traffic, grade, subsoil, etc., require the selection of different kinds of pavement to meet different conditions. A street which requires a stone block pavement in one section, may call for asphalt and macadam in other sections. Likewise, in the case of rural highways dirt, gravel and broken stone should each be used to meet the varying conditions which may be present. For the same reason the specifications for building the different pavements should vary. Often in laying a brick pavement, a concrete foundation is an unnecessary luxury. A macadam pavement five inches thick is frequently as satisfactory as a thicker one. Often a road is not traveled sufficiently to justify a macadam pavement, in which case gravel or dirt should be used. A careful study of pavements is instructive, provided it is conducted with a knowledge of the manner in which the pavement was constructed, the quality of the materials used, the traffic conditions and the climatic changes. Mere observations as to the appearance of the pavement are of very little value. Summing up everything we may conclude that each street or road is "a law unto itself."

In a general way it may be said that for residential streets in cities, for streets in small towns and villages and for rural highways the most desirable pavements are macadam and telford. For light business traffic, brick, asphalt and wooden block pavements are most serviceable. For heavy traffic streets, granite block pavements are usually most durable.

As business encroaches upon the residence districts of a city

the kind of pavement required to meet the changing traffic conditions will change, brick or asphalt supplanting macadam, and stone block in turn supplanting these. There must be evolution in the paving, as well as in the erection of buildings. The old must be torn down, and new built in their stead. Through this entire process care must be exercised in selecting the material best adapted to the conditions which may exist at the time the pavement is constructed; the best quality of material should be used; the method of construction should be the best, and, finally, ample provision should be made to protect and preserve the pavement by a wise system of maintenance.

SMOOTH TRACKS.

One of the chief objections to the stone block pavement is its uneven surface. It is more difficult for a horse to pull a load over a rough surface than over a smooth one. The rough surface, however, is an advantage on steep grades, since it gives horses a foothold. The desirability of providing a pavement which furnishes a foothold, and at the same time a smooth surface for the wheels, has led to the suggestion of laying a stone block pavement with tracks in which wagon wheels may run. The advantage of this is clearly illustrated by the street car tracks, which are constantly used by teamsters in the large cities. In fact, were it not for the car tracks, it would be necessary to haul much smaller loads than at present over many of the streets.

The laying of steel wagon tracks would be very expensive, and for this reason they are practically out of consideration. It has been suggested, however, that the same object might be accomplished by laying alternating strips of block and sheet pavement. The strips of sheet pavement might be laid the width of the street car tracks apart and about ten inches wide. If two tracks of this kind, built out of concrete or asphalt, were constructed in conjunction with a stone block pavement the value of the pavement should be materially increased. The blocks would provide the desired foothold and the strips of sheet pavement an unobstructed wheel track.

SIZE OF LOADS.

The maximum load that can be hauled over any road is the load that can be moved over the poorest part of that road. It frequently happens that a team can draw with ease 4,000 or 5,000 pounds over three-fourths of a road and only two thousand over

the remainder. This limits the load to 2,000 pounds. If possible, a road should be so laid out and improved that a load can be drawn over all parts with equal ease.

Horses can usually pull a very heavy load up a short, steep incline, provided they put forth an extra exertion. This extreme exertion, however, cannot be sustained for any great length of time. In establishing the grade of a road it is sometimes advisable to bring portions of it into short steep pitches, with nearly level stretches between, in order to secure a maximum efficiency.

A glance at the table, pages 102 to 104, will give some idea of the weight of load hauled over many of the highways in this State. In some counties the average load is very small, and in all of them it is smaller than it should be.

PAVEMENTS AND THEIR RELATIONS TO THE DURABILITY OF HORSES AND VEHICLES.

Very little consideration has been given to the effect which different pavements may have upon the life of horses and vehicles. I believe, however, that this is a matter worthy of consideration.

Experience seems to show that asphalt is the hardest on horses. In the summer it is often hot and soft, permitting the wheels to sink into it, while in winter it is smooth and slippery. Brick and block pavements injure a horse by causing him to throw his weight to one side.

From the standpoint of the man who drives a horse, properly constructed macadam pavements are most desirable. The number of years that a horse will remain serviceable depends upon the kind of pavement he is driven over, in the following order: Macadam, wooden block, brick, stone block, asphalt. Light and heavy delivery horses will lose from 5 to 10 years of their serviceable life when driven over asphalt or block pavements, compared with macadam.

Rubber tires are said to have lessened the repairs to vehicles about fifty per cent. "With respect to the serviceability of vehicles, it appears that the pavements rank about as follows: Asphalt, macadam, wooden block, brick, stone. The average period of serviceability of a vehicle driven over city pavements does not exceed ten years. Most of the injuries to vehicles arise from driving over stone block pavements. On sheet pavements the injuries are chiefly a result of turning out of street car tracks and cannot be attributed to the nature of the pavement itself." The city en-

gineer should consider, not only the problem of constructing a durable pavement, but also that of reducing to a minimum the cost of maintenance of the horses and vehicles.

THE PASSENGER AND THE PAVEMENT.

Our residence streets, park drives and rural highways should be paved in such a manner as to make them agreeable to drive over. The cleaner and smoother the pavement the more agreeable it is. Stone block and partly worn wooden block pavements are not suitable for pleasure driving. Macadam, asphalt, bitulithic macadam and smooth, newly constructed brick and wooden block pavements are the pleasantest to ride over.

The only objection to these pavements, when they are properly maintained, is the dust which constantly accumulates on their surface. Limestone macadam is especially disagreeable in this respect unless it is systematically sprinkled. When very wet this dust forms a sticky mud which is likewise disagreeable. In the case of asphalt, brick, wooden block, bitulithic macadam and trap rock macadam there is very little danger of mud, provided the pavements are given ordinary care.

THE RESIDENT AND THE PAVEMENT.

Cleanliness and noiselessness are the characteristics most desired by the people past whose property a pavement is constructed. Macadam and wooden block are the quietest pavements. Brick, asphalt and modern wooden block pavements are considered the cleanest. It is difficult to select a pavement which will meet both of these requirements, but it is thought that the modern wooden block comes the nearest.

The taxpayer, the teamster, the pleasure driver, the resident, the horses and the vehicles, all have an interest in the kind of pavement to be constructed. All these varied interests cannot be satisfied, and the city must build a pavement which meets the demands of the majority. Recognition, however, must be given the user as well as the taxpayer and the builder.

MAINTENANCE.

A permanent, systematic method of maintenance for all pavements is imperative. In the small cities, towns and villages, with only a few blocks of pavement, this is not a difficult problem. In the large cities it becomes a serious problem, demanding the serv-

ices of a small army of men. Paved streets must be kept up, if it is expected to obtain from them the best service.

The cleaning, repairing, sprinkling and superintendence should be under control of either a board of public works or a street commissioner. The city should be laid off in districts, each of which should be in charge of an overseer. This man, with necessary laborers, should keep the pavement and sidewalks in repair; keep the pavements, gutters, crosswalks and sidewalks clean; regulate the sprinkling; remove snow and ice, and care for the parked areas and shade trees. Tools, carts and necessary materials for repairing should be furnished by the city and kept in a convenient place.

Overseers should be employed for an indefinite term, and they should not be dismissed from the service except for good and sufficient reason. After a few years an overseer, under proper instructions, should become very proficient. Gillespie says: "The labor of one man will keep in repair three miles of well-made and well-drained road for the first two years after its formation and four miles for the next two years." He further says that to keep a road in good condition requires two fundamental operations:

"1. The continual removal of the daily wear of the materials, whether in the shape of mud or dust.

"2. The employment of materials to replace those removed."

In the case of macadam pavements, crushed rock to be used in making repairs should be placed in convenient bins at the side of the street. A house should be built in which the overseers of four contiguous sections may keep their tools.

If the city is provided with waste paper boxes, ash cans and garbage boxes, it should be the duty of the overseer to see that these are emptied as required by the city ordinances.

This plan of dividing the streets of a city into sections should be applied to all improved country roads. The usefulness of the improvements to country roads will be increased many fold thereby.

THE USE OF CONVICT LABOR.

In some states convict labor is used successfully in improving the highways. There should be no objection to the use of all able-bodied prisoners in the State penitentiary and in county and city jails, in the improvement of the public highways. The employment of this army of men on our highways would result eventually in the construction of many miles of pavement in any state where the plan is carried out in a systematic manner.

Every city and county should have a workhouse, equipped with a rock crusher, to provide employment for vagrants. It will either result in the improvement of the highways or in the lessening of the number of convicts in our prisons.

STATE AND COUNTY HIGHWAYS.

Road construction and maintenance should be placed under the control of persons especially trained for this work. A State Highway Commission will do much to improve the present condition, and should the State at any time provide funds for constructing pavements such a commission will be needed to administer the funds and supervise the work.

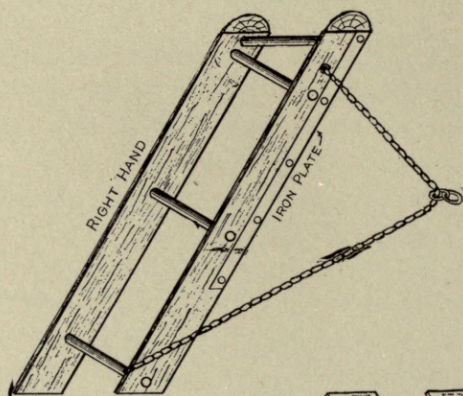
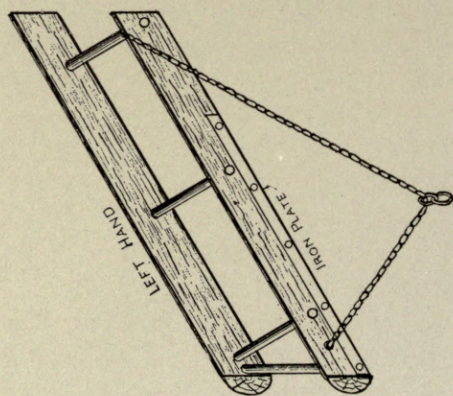
The county surveyor should be a superintendent of highways and bridges. He should be one of the best paid officers in the county, and should be equipped with a full knowledge of the methods of improving and maintaining the public roads.

Each town might in turn have a deputy surveyor, under the supervision and direction of the county surveyor, and to whom the immediate supervision of construction and maintenance could be entrusted.

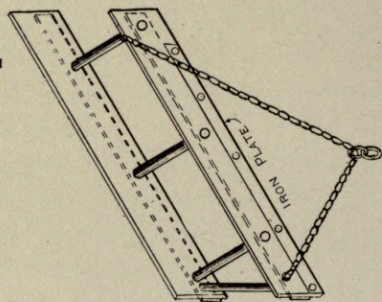
What is needed more than anything else, at present, is an intelligent supervision of the expenditure of the moneys now available for the improvement of our roads. We must also abandon the plan of "working out" the road tax. This is an inheritance which we have long since outgrown.



King's Split-log Drag.



Plank Drag.



THE KING SPLIT-LOG DRAG.

APPENDIX.

Mr. D. Ward King of Maitland, Missouri, has given to our people a rich heritage in the "Split-log" drag. When intelligently handled and persistently applied to a dirt road it works a wonderful transformation in a very short time. Knowing that this volume may fall into the hands of some who will desire to know how to construct and handle the King drag, this appendix on "How to Make and Operate a Drag" has been inserted.

HOW TO MAKE AND OPERATE A DRAG.*

"The most common mistakes that I see as I go about are: First, making the drag too big and heavy, and, second, using timbers with too wide a face on the ground.

The Split-Log Drag.—Take the two halves of a split log, ten or twelve inches thick and seven to nine feet long. Set the halves flat sides to the front, fasten thirty inches apart with strong stakes, the ends of which are wedged in two-inch auger holes, bored through the slabs. Put a solid plank platform on the stakes for the driver to stand on. The hitch is made of strong wire or chain, the long end fastened to stake over the top of the front slab, the short end should be put through a hole made in center of the slab and near the end to prevent the back slab tilting forward. Face four or five feet of the ditch end of the front slab with iron. An old wagon tire, worn share of road grader, or any piece of flat steel will answer for this purpose."

"Plank Drag.—The half of a split log is, without any doubt whatever, the best shape for drag material. I have made several splendid ones from the ends of cedar telephone poles. If forced to use plank, get elm or cypress, 2"x12" of the proper length, and a 2"x6" of the same length. Use the 2"x6" to reinforce the 2"x12" lengthwise of its center, so that there will be four inches in thickness of the wood through which to bore the two-inch holes for the stakes

*Extract from Bulletin No. 10, Vol. V, Missouri State Board of Agriculture, written by D. Ward King, Maitland, Mo.

which are to join the two slabs. By this arrangement of the plank the shape of the log slab is approximated."

"I have seen a great many drags made in numerous different styles, but I find nothing that suits me better than hedge, or straight oak stakes. Money spent on long bolts or eye bolts is wasted. If the stakes are properly wedged, long bolts are useless."

"Instead of eye bolts to fasten the chain, simply wrap one end of the chain around an end stake, carry it over the top of the slab, out to the double trees, and then back to the other end of the slab, where the chain should be slipped through a hole bored in the end of the slab and can be fastened by poking an old bolt or spike through one of the links. This hole should be bored only three or four inches from the end of the slab and about its center, up and down. This is inexpensive, strong, durable and puts the rear end of the chain up out of the way of the dirt as it drifts along the face of the slab."

DETAILS.

"After splitting a log, when you place one of the slabs on edge with the face of one end plumb, the face at the other end will not be plumb; will not be at right angles with the floor. By selecting the proper one of the slabs for the front of the drag this obliqueness can be used to give the ditch end of the slab a chisel-like action on the road surface, while the other end of the same slab will have its face perpendicular or plumb. This is a fine point and may be a little hard to see, but it will pay big if you can grasp the idea. The same effect is produced by inserting a three-cornered strip of wood under the steel at the ditch end of a plank drag."

OPERATION.

"As a general rule, always haul the drag at an angle of 45 degrees, moving the dirt to the center of the road. The action of the drag is covered by four things:"

"1st. *The Length of the Chain*, which is regulated by slipping it backward or forward through the hole in ditch end of drag. The length of the chain regulates the hold taken on the earth. To make the chain longer is equivalent to putting weight on the drag. If your drag is too heavy, shorten the chain."

"2nd. *The Position of the Snatch Hook*, which attaches the double trees. To move much dirt or cut small weeds hitch the hook close to the ditch end of drag and stand as nearly on the end

of the front slab as is safe. Drive very slowly when thus hitched. This one hitch seems to be the hardest to learn. The others suggest themselves."

"3d. *Position of the Driver on the Drag.*—To move dirt see above. In a soft spot stand on rear slab. On a hard spot stand on front slab and drive slowly. If the drag clogs with straw, weeds, sod or mud, step to a point as far as you can get from ditch end of drag. To drop dirt in a low place step quickly from ditch end to other extreme. To fill a low place or mud hole nicely is the severest test of skill with a drag."

"4th. *Presence or Absence and Sharpness or Dullness of the Steel.*—The steel may project half an inch below the wood at the ditch end of the steel, but should come up flush with the wood at other end of the steel. After a clay or gumbo road has been dragged four or five years the soil becomes so tough and putty-like that one must study it closely to know what to do. Sometimes I use sharp edge of steel; sometimes dull edge (holes are bored in both edges of steel so that I can turn it upside down and use same bolt holes), and sometimes the plain wood."

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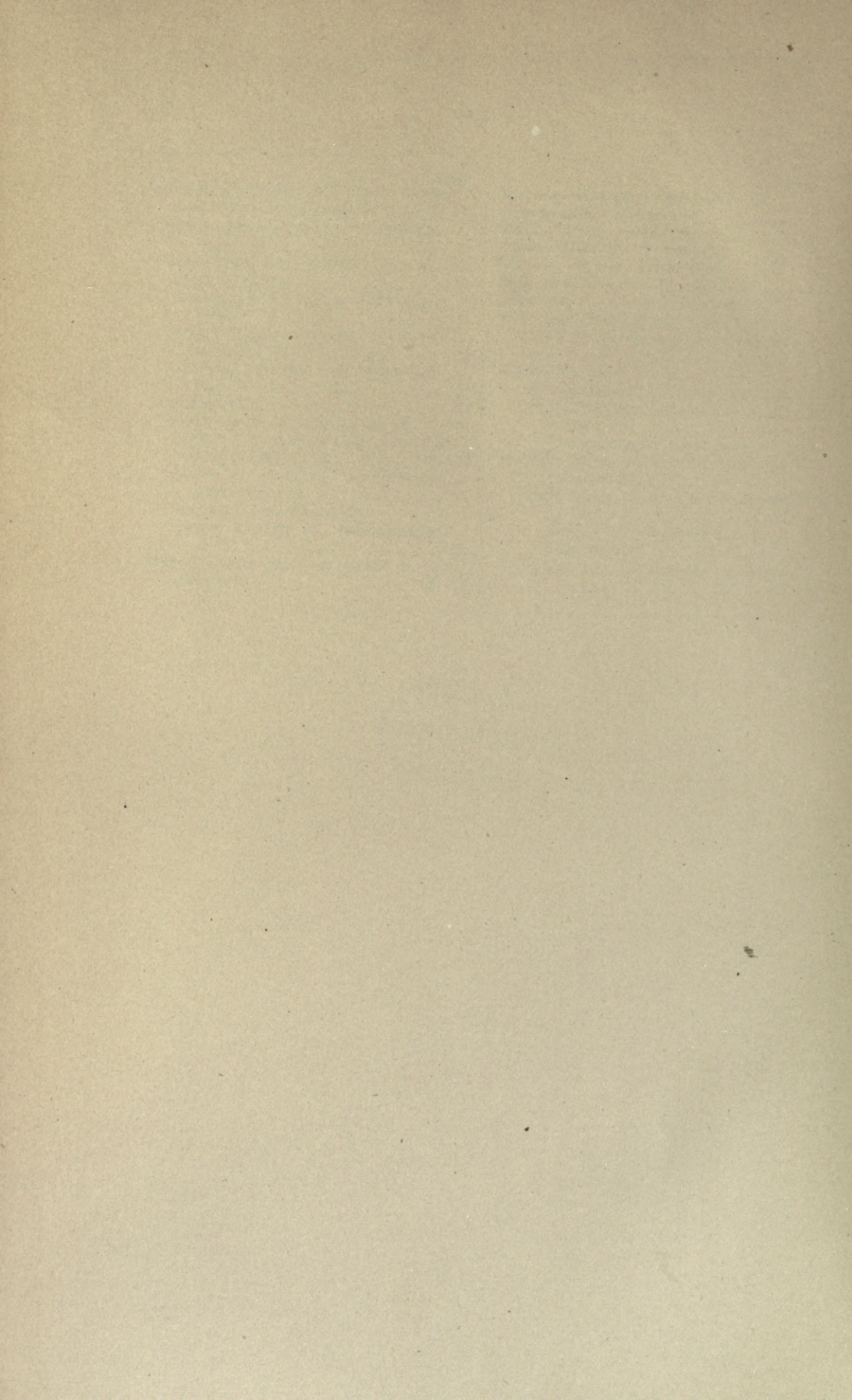
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